Dissertation on

"A STUDY ON PORTAL VEIN AND ITS INTRA-HEPATIC BRANCHING PATTERN"

Submitted in partial fulfillment for

M.D. DEGREE EXAMINATION

BRANCH- XXIII, ANATOMY

Upgraded Institute of Anatomy

Madras Medical College & Rajiv Gandhi Government General Hospital,

Chennai – 600 003

THE TAMILNADU DR. M.G.R. MEDICAL UNIVERSITY

CHENNAI – 600 032

TAMILNADU

APRIL 2016

LEGEND

MPV/PV	–	Main Portal Vein
RPV	–	Right branch of Portal Vein
LPV	–	Left branch of Portal Vein
RAD	–	Right Anterior Division
RPD	–	Right Posterior Division
IVC	–	Inferior Vena Cava
SMV	–	Superior Mesenteric Vein
SV	–	Splenic Vein
IMV	-	Inferior Mesenteric Vein
LHV	–	Left Hepatic Vein
MHV	–	Middle Hepatic Vein
RHV	–	Right Hepatic Vein
GB	-	Gall Bladder
CBD/BD	-	Common Bile Duct
HA	-	Hepatic Artery
PT	-	Pars Transversalis
PU	-	Pars Umbilicalis
MB	-	Medial Branch
AB	-	Accessory Branch
LSB	-	Lateral Superior Branch
LIB	-	Lateral Inferior Branch
Sup	-	Superior
Inf	-	inferior
CT	-	Computed Tomography
MDCT	-	Multi Detector Computed Tomography
CTAP	-	CT during Arterial Portography
MRI	-	Magnetic Resonance Imaging
PVE	-	Portal Vein Embolization

CERTIFICATE

This is to certify that the dissertation titled**, "A STUDY ON PORTAL VEIN AND ITS INTRA-HEPATIC BRANCHING PATTERN"**submitted by **Dr.N.V.GANGA,** in partial fulfilment for the award of the degree of Doctor of Medicine in Anatomy, Branch-XXIII by The TN Dr.MGR Medical University, Chennai is a Bonafide record of the work done by her in the Institute of Pharmacology, Madras Medical College during the academic year 2013-16.

Dean
Madras Medical College &
Rajiv Gandhi Govt. General Hospital
Chennai – 600 003.

Dr.Sudha Seshayyan, M.B.B.S., M.S.,
DIRECTOR AND PROFESSOR,
Institute of Anatomy,
Madras Medical College,
Chennai – 600 003.

CERTIFICATE OF THE GUIDE

This is to certify that the dissertation titled, **"A STUDY ON PORTAL VEIN AND ITS INTRA-HEPATIC BRANCHING PATTERN"** submitted by **Dr.N.V.GANGA** in partial fulfilment for the award of the degree of Doctor of Medicine in Anatomy, Branch-XXIII by The TN Dr.MGR Medical University, Chennai is a record of original work done by her under my guidance and supervision in the Institute of Anatomy, Madras Medical College during the academic year 2013-16.

Place:
Date:

Dr.Sudha Seshayyan, M.S., PDHM,
Director and Professor,
Institute of Anatomy,
Madras Medical College,
Chennai- 600 003.

DECLARATION

I, **Dr.N.V.GANGA,** solemnly declare that the dissertation titled **"A STUDY ON PORTAL VEIN AND ITS INTRA-HEPATIC BRANCHING PATTERN"**has been prepared by me and submitted to TN Dr.MGR Medical University, Chennai in partial fulfilment of the rules and regulations for the M.D. degree examination in Anatomy.

Date: **Dr. N.V.GANGA**

Place**:**

INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE, CHENNAI-3

EC Reg No.ECR/270/Inst./TN/2013
Telephone No. 044 25305301
Fax : 044 25363970

CERTIFICATE OF APPROVAL

To
Dr. N.V.Ganga
Postgraduate M.D.(Anatomy)
Madras Medical College
Chennai – 600 003.

Dear Dr.N.V.Ganga,

The Institutional Ethics Committee has considered your request and approved your study titled **"A study on portal vein and its intrahepatic branching pattern" No. 21122014.**

The following members of Ethics Committee were present in the meeting held on 02.12.2014 conducted at Madras Medical College, Chennai-3.

1. Dr.C.Rajendran, M.D.,	: Chairperson
2. Dr.R.Vimala, M.D., Dean, MMC, Ch-3	: Deputy Chairperson
3. Prof.B.Kalaiselvi, M.D., Vice-Principal, MMC, Ch-3	: Member Secretary
4. Prof.R.Nandini, M.D., Inst.of Pharmacology, MMC	: Member
5. Prof.P.Ragumani, M.S., Professor, Inst.of Surgery, MMC	: Member
6. Prof.Md.Ali, M.D., D.M., Prof. & HOD of Medl.G.E., MMC	: Member
7. Prof.K.Ramadevi, Director, Inst.of Biochemistry, MMC	: Member
8. Prof.Saraswathy, M.D., Director, Pathology, MMC, Ch-3	: Member
9. Prof.S.G.Sivachidambaram, M.D., Director i/c, Inst.of Internal Medicine, MMC	: Member
10. Thiru S.Rameshkumar, Administrative Officer	: Lay Person
11. Thiru S.Govindasamy, B.A., B.L.,	: Lawyer
12. Tmt.Arnold Saulina, M.A., MSW.,	: Social Scientist

We approve the proposal to be conducted in its presented form.

The Institutional Ethics Committee expects to be informed about the progress of the study and SAE occurring in the course of the study, any changes in the protocol and patients information/informed consent and asks to be provided a copy of the final report.

9/12/15

Member Secretary, Ethics Committee

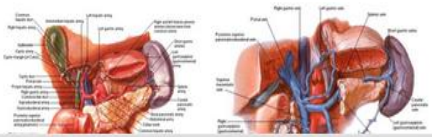
MEMBER SECRETARY
INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE
CHENNAI-600 003

INTRODUCTION

The hepatic portal vein starts as well asends as capillaries.The portal vein transfers the end products of digestion from stomach to upper part of rectum and blood from the spleen to the liver. The hepatic sinusoids are filled with both portal venous and hepatic arterial blood. This blood is returned to the heart through the hepatic veins and the inferior vena cava.

Portal veinabout 8 cm long is formed by the union of superior mesenteric and splenic veins. This union takes place behind the neck of pancreas and in front of inferior vena cavaat L2 vertebral level.The superior mesenteric and portal vein is formed as a single continuous venous trunk.The part above the level of entry of splenic vein is named as portal vein and the part below it called superior mesenteric vein.The adult Portal vein lacks functioning valve. The blood flow is streamlined and slow.

Portal vein – Formation, Course, Tributaries and Relations



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I'm grateful to my **Husband, Parents, Children, Mrs.Rani, Mr.Sathya Narayanan** and my friends **Dr.G.Kannan, Dr.V.Pandiyan, Dr.M.Chitra,** and Adyar Students Xerox, Guindy Branch who have helped making this study a reality.

Above all, I thank the **ALMIGHTY GOD** who has showered his choicest blessingon me and guided me in every step of the dissertation.

CONTENTS

ABSTRACT

The present study describes the intra-hepatic branching pattern of portal vein in human liver obtained from Embalmed Cadavers at Institute of Anatomy, Madras Medical College. Manual dissection and Radiological method were used for this study. The portal vein was traced from its course to the various segments of the liver. The most common variant is trifurcation of the portal vein. The portal variants must be diagnosed before surgical and interventional procedures. The aim of the present study is to review portal venous anatomy and its clinical implications.

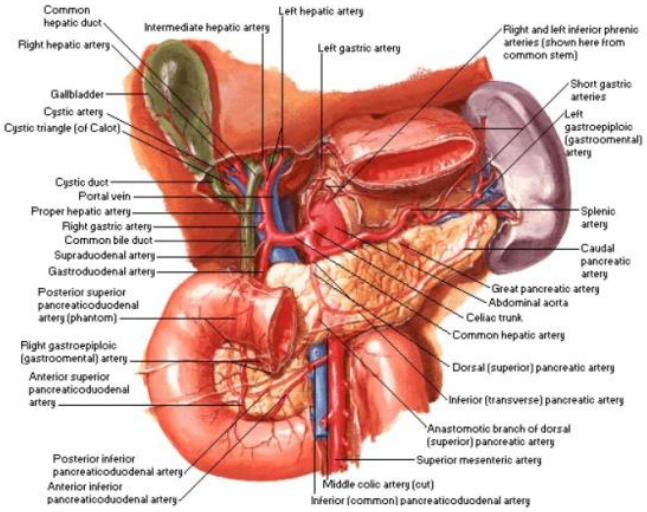
Keywords: Portal vein, branching pattern, Bifurcation, Trifurcation, Ramification, Right Portal Vein, Left Portal Vein, Segments, Right lobe, Left lobe.

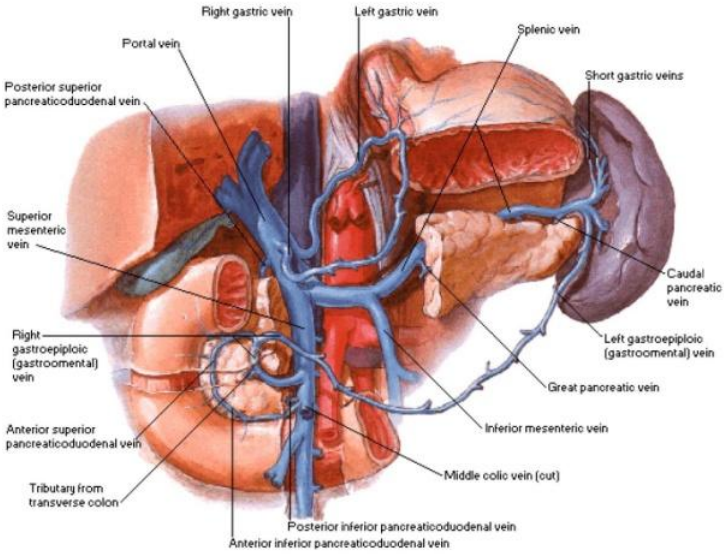
INTRODUCTION

The hepatic portal vein starts as well as ends as capillaries. The portal vein transfers the end products of digestion from stomach to upper part of rectum and blood from the spleen to the liver. The hepatic sinusoids are filled with both portal venous and hepatic arterial blood. This blood is returned to the heart through the hepatic veins and the inferior vena cava.

Portal vein about 8 cm long is formed by the union of superior mesenteric and splenic veins. This union takes place behind the neck of pancreas and in front of inferior vena cava at L2 vertebral level. The superior mesenteric and portal vein is formed as a single continuous venous trunk. The part above the level of entry of splenic vein is named as portal vein and the part below it called superior mesenteric vein. The adult Portal vein lacks functioning valve. The blood flow is streamlined and slow.

Portal vein – Formation, Course, Tributaries and Relations

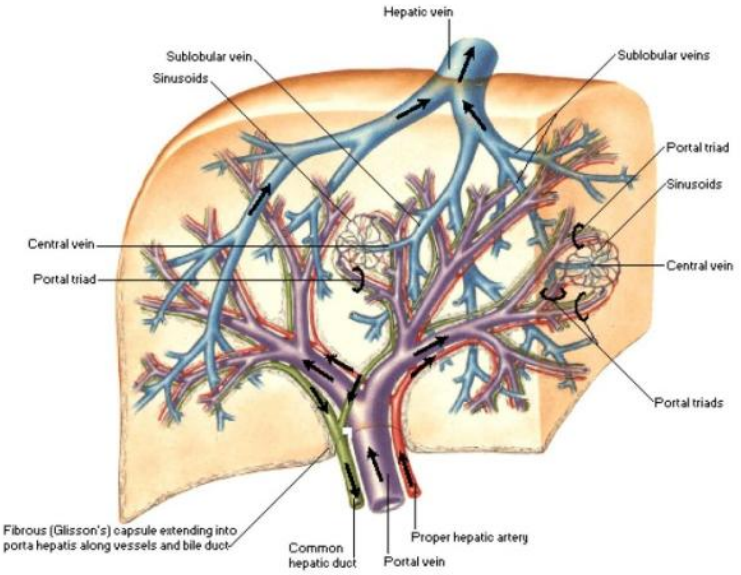




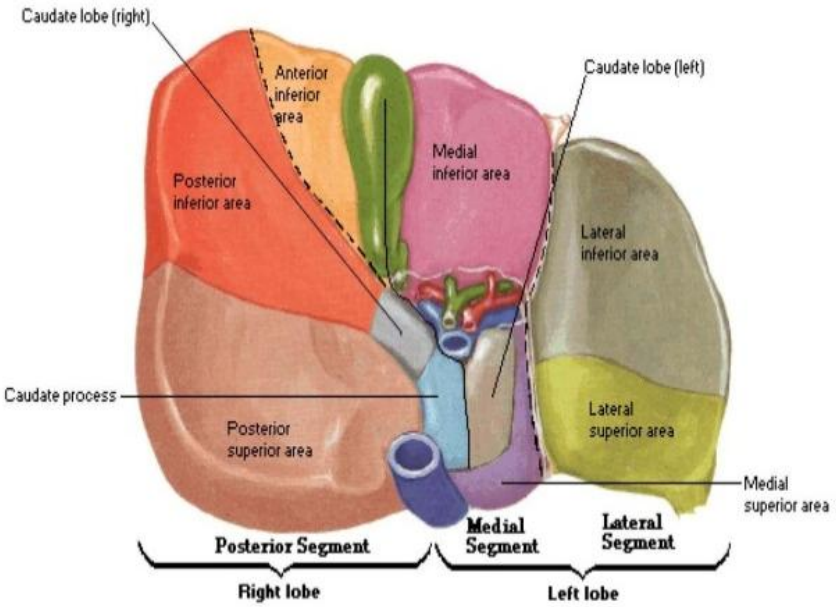
It ascends obliquely to the right behind the first part of duodenum. Above the duodenum it enters the right free margin of lesser omentum and finally reaches the right end of porta hepatis. Its lower part is placed on the posterior abdominal wall in front of inferior vena cava. The portal vein is separated from the first part of duodenum by the bile duct and gastro-duodenal artery. In the lesser omentum it is separated from inferior vena cava by epiploic foramen and lies posterior to bile duct, hepatic artery. At porta hepatis it is separated from inferior vena cava by caudate process of liver.

The Portal vein usually ramifies into right and left stem at porta hepatis. Both the branches enter into the substance of liver and accompany the corresponding branches of hepatic artery. In the liver Portal vein ramifies like an artery in a regular manner and determines segments within the sector (determined by hepatic vein) along with hepatic artery and bile duct. So the hepatic veins are inter-segmental and intertwined with portal radicles.

Branching pattern of portal vein



Classification of segments (Visceral surface of liver)



Right main branch of portal vein is shorter (2-3cm) and wider. Usually divide into anterior/medial and posterior/lateral branches, each divides into superior and inferior branches supplying segments VIII, V and VII and VI respectively. Branch to caudate lobe (segment I) may arise from medial division. Variation usually involves the right main branch.

Left branch is longer (4-5 cm) and narrower. It has horizontal part (pars transversalis) and vertical part (pars umbilicalis). The horizontal part furnishes branch to caudate lobe and continues laterally to supply left posterior lateral sector (segment II). The main part turns vertically divides into left anterior medial (segment IV, quadrate lobe) and left anterior lateral branch (segment III).

Its formative tributaries are splenic vein and superior mesenteric vein, also inferior mesenteric vein occasionally. Tributaries that drains into trunk are right gastric, left gastric, superior pancreaticoduodenal. The cystic and paraumbilical vein drains into main branches of portal vein. The cystic vein drains into right branch of portal vein usually but can also drain into main portal vein. The paraumbilical vein which runs along the ligamentum teres joins the left branch of Portal vein. Porto-systemic communication is an important route of collateral circulation in portal obstruction.

The blood from the sinusoids drains into central vein, intra-lobular vein, sub-lobular vein, major hepatic veins successively. The hepatic veins are arranged in two groups upper and lower. Upper group consists of right, left and middle. The middle one emerges from caudate lobe. Lower group variable in

number drains caudate and right lobe of liver. The hepatic veins emerge from the posterior surface of liver.

Left hepatic vein runs between medial and lateral segment. Right hepatic vein runs between anterior and posterior segment. Middle hepatic vein runs between physiological right lobe and left lobe of liver. Usually left and middle join together and drains into inferior vena cava. Right hepatic vein drains into inferior vena cava independently. Sometime all the three opens independently.

AIM OF THE STUDY

Anatomical knowledge of Portal vein and its branching pattern is important for Surgical Gastroenterologist & Interventional Radiologist. Portal vein variations are relatively common and pre-surgical awareness is important as portal vein along with hepatic vein determines the segmental anatomy. Hepatic veins are inter-segmental.

Evaluation of portal vein anatomy and its variations is of utmost important in Selection of donors for living adult liver transplantation, segment resection, portal vein embolization, shunt procedures etc to ensure surgical success. Since 80% of the blood supply to liver is by Portal vein, ligation of its extra-hepatic division is very important to control hemorrhage in major liver surgeries. Bile duct variations should be ruled out if any variation in the Portal vein is noted.

Many variations in the branching pattern of portal vein have been reported in the literature. Portal trifurcation is considered as relative contraindication for split liver and live donor transplantation. Liver transplantation requires anastomoses of Portal vein after Inferior vena cava. Liver resection for primary tumors follows plane between segments and are anatomical.

If Portal Vein remains as single trunk it is a contraindication for major liver surgery which is very rare. If Left branch of portal vein originates from right anterior branch resection of right hemi-liver is warranted. Variations are commonly encountered as a result of imaging techniques. In short knowledge

on Portal vein variations like trifurcation, quadrifurcation, single trunk, absence, accessory portal vein and right branch Portal vein variations are all important in living liver donor transplant.

Obstruction of portal vein at any level may occur due to cirrhosis of liver, tumor, thrombosis or enlarged lymph nodes. To relive the obstruction to some extent in severe portal hypertension anastomosis can be done between Portal vein and inferior vena cava a procedure called Trans-jugular intraparenchymal porto-systemic shunt (TIPS).

Cadaveric liver dissection and Corrosion casts were done previously to review knowledge on intra-hepatic branching pattern of portal vein.

Now with the use of modern techniques like multi-detector Computed tomography and Magnetic Resonance Imaging, it is possible to know the vascular anatomy in a 3dimensional images accurately in a non-invasive manner.

The aim of this project is to study in detail about the formation, division, branching pattern and to look for any variations in cadaveric liver specimens and in multi-detector Computed tomography.

PARAMETERS

1) Formation of portal vein
2) Level of formation
3) Length of portal vein
4) Relation of Portal vein in porta hepatis

5) Division of Portal vein at porta hepatis

6) Branching pattern of portal vein

A) Bifurcation (standard anatomy)

B) Variant branching pattern

i) Trifurcation

ii) Other variations

7) Right branch of portal vein (1^{st} order branch)

A) Origin of RPV

B) Length of RPV

C) Mode of termination

8) Right anterior division (2^{nd} order branch)

A) Origin of RAD

B) Mode of termination

9) Right posterior division (2^{nd} order branch)

A) Origin of RPD

B) Mode of termination

10) Left branch of portal vein (1^{st} order branch)

A) Origin of LPV

B) Length of LAD

C) Mode of termination

11) Branch to caudate lobe

12) Branch to quadrate lobe

13) Accessory branches

14) Relations of portal vein with hepatic vein

HISTORICAL BACKGROUND

Glisson, (1659) was the first person who enumerated the intra-hepatic vascular anatomy in "Anatomic Hepatics" by cast. He also explained the relation of Portal Venous and Hepatic venous systems.

Rex. (1888) based on corrosion cast study both in human and in non human mammals established a nomenclature for branching pattern of the portal vein and also for the major hepatic veins.

Looten, (1908) claimed the vascular independence of PV in both lobes of liver.

Segall, (1923) gave general information on hepatic vasculature and bile duct.

Melnikoff, (1924) reported that the hepatic and portal veins are intertwined.

Hjortsjo, (1948) studied the vasculature of liver by injecting the colored colloidin and stated caudate lobe receives its vasculature from the left branch only.

Bruce E Douglas, (1950) quoted that the portal vein arises by confluence of abdominal visceral veins and ends in liver by dividing into right and left branches.

Couinaud (1952) framed nomenclature and widely accepted today.

The right lobe is divided into anteromedial and posterolateral sectors. Anteromedial into inferior (segment – V) and superior (segment – VIII). Posterolateral into inferior (segment – VI) and superior (segment – VII).

The left lobe of liver is divided into lateral anteroinferior (segment – III), lateral posterosuperior(segment – II) and medial (segment – IV).

He subdivided the caudate lobe into paracaval (segment IX) and spigelian (segment – I) portion. Since its vasculature anatomy is independent he named it as an autonomous segment.

He also enumerated various pattern of trifurcation.

In type 1: Right anterior, right posterior and left branch all arises directly from the main portal vein (immediate trifurcation).

In type 2: Divides into right anterior and left branch after giving out right posterior branch.

In type 3: The PV continues as left branch after giving out right posterior segment. Right anterior branch arises from left branch.

Bismuth (1982) quoted that the caudate lobe is independent in its portal and hepatic venous system.

REVIEW OF LITERATURE

1. PORTAL VEIN FORMATION

G.J.Romanes[59] (1972) mentioned that the PV is formed behind and to the left of head of pancreas by the union of SMV and SV. He mentioned that IMV may open at the confluence of SV and SMV occasionally.

W.HenryHollinshead[20] (1976) stated that IMV may open at the confluence of SMV and SV and so the formation of portal vein.

John V.Basmajian[28] (1979) quoted that the portal vein is formed by the union of SV, SMV and IMV behind the neck of pancreas. The splenic vein corresponds to splenic artery.

Susan standring[68] (2008) said that PV is formed by the union of SMV and SV.

Keith L Moore [29] (2010) stated that the PV is formed by the union of SMV and SV. In 1/3rd of individuals it is formed by SMV, IMV and SV.

S.Sinnatamby Chummy [8] (2011) mentioned that the SMV continues upward as PV. The name is changed to portal after it receives splenic vein.

Michel N [44](1956) reported a case of double portal vein and mentioned the incidence as 1 in 500. The 2nd one was anterior to the main PV and formed by the union of retro-duodenal vein and vein draining the lesser curvature of stomach.

Bergman et al (1988) reported a case of absent PV and opening of SMV and SV into renal vein.

Jin Shan et al (1996) reported a case of accessory portal vein.

Mindy Northrup et al (2002) reported a case of absent portal vein. SMV and SV open into IVC above the opening of renal vein.

Gorantla et al[70] (2007) mentioned anomalous formation of PV, a case report. In this case PV was formed by the union of SMV, SV and IMV. Left gastric vein was terminated in SMV before PV formation.

Pre-duodenal portal vein and pre-pancreatic post duodenal portal vein have been reported in literature.

2. LEVEL OF FORMATION

Susan standring[68] (2008) stated that it begins at the level of L2 vertebra.

Keith L Moore[29] (2010) mentioned that PV arises at the level of L1 vertebra.

Neeta V Kulkarni[50] (2012) quoted that it starts at the level of L2 vertebra.

3. LENGTH OF PORTAL VEIN

G.J.Romanes[56] (1972) quoted that PV is a wide channel and its length is about 7.5 cm.

Susan standring[68] (2008) stated that its length is approximately 8cm.

Keith L Moore[29] (2010) stated that it runs a short course mostly within the hepatoduodenal ligament and its length averages about 7-8 cm.

S.Sinnatamby Chummy[8] (2011) quoted that PV length is about 8cm

Neeta V Kulkarni[50] (2012) mentioned that the length of extra-hepatic part of PV is 8-10 cm.

4. RELATION IN PORTA HEPATIS

G.J.Romanes[56] (1972) stated that it ascends upwards within the lesser omentum in front of inferior vena cava separated by epiploic foramen and reaches the right end of hilum. At portahepatis it lies posterior to the CBD and hepatic artery.

W.HenryHollinshead[20] (1976) mentioned that PV lies behind common bile duct and proper hepatic artery and to the left of common bile duct.

John V.Basmajian[28] (1979) quoted that the portal vein terminates at right end of portahepatis and lies behind the common bile duct and HA.

S.C.Gupta et al[16] (1997) stated that PV at portahepatis was behind the common bile duct and hepatic artery by analyzing 85 liver specimens by cast.

Susan standring[68] (2008) stated that PV lies posterior to common bile duct and hepatic artery at portahepatis.

S.Sinnatamby Chummy[8] (2011) said that PV is enclosed between 2 layers of lesser omentum which itself anterior to epiploic foramen. Within the lesser omentum it lies behind the hepatic artery and common bile duct.

5. DIVISION OF PORTAL VEIN

G.J.Romanes[56] (1972) stated that the PV reaches the right end of portahepatis and bifurcates at portahepatis into right branch (shorter and wider) and left branch (longer and narrower).

W.Henry Hollinshead[20] (1976) quoted that the PV terminates at portahepatis by dividing into 2 branches- right and left.

John V.Basmajian[28] (1979) mentioned that the portal vein divides into 2 branches the right and left at portahepatis.

Margaret et al[40] (1990) analyzed color Doppler ultrasound of 18550 patients and noted single trunk in 4 patients

S.C.Gupta et al[16] (1997) studied 85 liver specimens by cast and observed that the division of PV was extra-hepatic in all specimens

Zaferkoc et al[74] (2007) analyzed MDCT images of 1384 patients and noted absence of PV bifurcation in 0.1% of cases.

Susan standring[68] (2008) mentioned that at hilum the portal vein ramifies into right and left branches. Also mentioned the absence of PV bifurcation and so the single trunk which is a rare occasion.

S.Sinnatamby Chummy[8] (2011) mentioned that PV after reaching the portahepatis branches into right and left before entering into substances of liver.

Sahoo et al (2014) reported a case of absent PV bifurcation at portahepatis and so the single intra-hepatic portal vein.

6. BRANCHING PATTERN OF PORTAL VEIN

A) BIFURCATION OF PV (Standard Anatomy)

Couinaud[9] (1952) studied103 liver specimens by cast and described bifurcation pattern in 83.5% of cases. That is division into right portal vein and left portal vein

Healey[19] (1954) dissected 25 liver specimens and observed bifurcation pattern in all specimens.

S.C.Gupta et al[16] (1977) done study by corrosion cast in 85 liver specimens and observed bifurcation pattern in 88%.

Yamane T et al[72] (1988) done study in 25 human liver casts and observed the normal branching pattern of PV in 80% of cases.

Margaret et al[40] (1990) analyzed color Doppler ultrasound of 18550 patients and noted bifurcation pattern in 18533 patients.

MostafaAtri[46] (1992) described bifurcation pattern in 80% of cases by analyzing USG images of 507 patients.

Philippe et al[53] (1994) analyzed helical CTAP of 69 patients and observed classical bifurcation pattern in 94%.

Akgul et al[1] (2002) analyzed contrast enhanced helical CT images of 585 patients and observed 86.2% had classical bifurcation.

Arora et al[3] (2003) studied ramification of portal vein in 15 liver specimens by corrosion cast and observed conventional bifurcation pattern of portal vein in all specimens

Covey et al[11] (2004) reviewed CT arterial portograph of 200 patients retrospectively and found 65% of cases had normal bifurcation pattern.

Atasoy and Ozyurek et al[4] (2006) reviewed 200 MDCT images of patients retrospectively and observed conventional bifurcation pattern in 65.5% of cases.

Zaferkoc et al[74] (2007) reviewed MDCT images of 1384 patients and concluded classical branching pattern in 78%

Susan standring[68] (2008) stated that portal vein divides into 2 branches the right and left.

Jean H.D.Fasel[26] (2008) did study in 20 liver specimens by manual dissection and observed normal bifurcation pattern in 17 cases (85%).

K.Maheswari[36] (2011) done study in 50 specimens by manual dissection, corrosion cast and dye injections. She observed bifurcation pattern in 82% of cases.

Jeremiah et al[49] (2014) dissected 100 livers specimens collected from Anatomy department, University of Nairobi, Kenya. They observed conventional bifurcation pattern in 51% of cases. .

Rajput et al[54] (2014) observed branching pattern of PV in right lobe of 25 livers by vascular casts and observed classical branching pattern in 92%

Macchiv et al (2015) studied 50 liver vascular casts and 200 CT images. They observed classical bifurcation pattern in 75% and 90% of cases respectively

B) VARIANT BRANCHING PATTERN OF PORTAL VEIN

i) TRIFURCATION OF PV

Couinaud[9] (1952) analyzed 103 corrosion cast specimens and noted trifurcation pattern in 16.5% of cases. Out of that type 1 pattern was observed in 7.8%, type 2 pattern in 5.8%, branching pattern of type 3 in 2.9%.

Healey[19] (1954) dissected 25 liver specimens and variation was not observed.

S.C.Gupta et al[16] (1977) did study in 85 liver specimens by corrosion cast and observed trifurcation pattern in 12%.

Yamane T et al[72] (1988) in their corrosion cast study of 25 human livers, found out trifurcation pattern in 20% of cases.

Margaret et al[40] (1990) analyzed color Doppler ultrasound of 18550 patients and noted trifurcation pattern in 6 patients. Type 1 pattern in 2 patients, type 2 in 2 patients, type 3 in 2 patients.

MostafaAtri[46] (1992) described similar branching pattern in 20% by analyzing USG images of 507 patients. Type 1 in 10.8% type 2 in 4.7%, type 3 in 4.3%.

Philippe et al[53] (1994) analyzed helical CTAP of 69 patients and observed that the PV divides into RAD, RPD and LPV in 4% of cases.

Van Leeuween[69] (1994) studied ramification of PV in 10 healthy volunteers by MRI procedure and observed trifurcation pattern in 2 subjects.

Akgul et al[1] (2002) analyzed contrast enhanced helical CT images of 585 patients and observed trifurcation in 13.5%. Noticed type 1 in 12.3%,type 2 in 0.3%,type 3 in 0.3%.

Arora et al[3] (2003) studied ramification of portal vein in 15 liver specimens by corrosion cast. They didn't get trifurcation pattern.

Covey et al[11] (2004) analyzed CT arterial portography of 200 patients retrospectively and found trifurcation pattern in 22% of cases. Out of that type 1in 9% of cases, type 2 (z type anatomy) in 13% of cases.

Zaferkoc et al[74] (2007) reviewed MDCT images of 1384 patients and concluded trifurcation pattern in 20.8% of cases. Out of that 11% had pattern -I and 9.8% had pattern-II type of trifurcation.

Atasoy and Ozyurek et al[4] (2006) reviewed 200 MDCT images of patients retrospectively and noted trifurcation pattern in 33% of cases. 9.5% of patients had type 1 pattern and 23.5% had type 2 pattern of trifurcation.

Wu Tc et al[71] (2007) reviewed MDCT images of 73 patients and found type 1 branching pattern in 13.3% of cases, type 2 in 3.3% of cases.

Sugo H et al[66] (2007), in a case report observed type 3 branching pattern of PV.

Zaferkoc et al[74] (2007) reviewed MDCT images of 1384 patients and concluded trifurcation pattern in 21% (type 1 in 11% and type 2 in 10%)

Susan standring[68] (2008) said that the prevalence of type 1 branching pattern is 10-15%. So that right branch of PV is absent. Also stated that right anterior portal vein may arise occasionally from left portal vein that is type 3 trifurcation pattern of portal vein

Jean H.D.Fasel[26] (2008) did study in 20 liver specimens by manual dissection and observed type 1 pattern in 5% of specimens and type 2 in 10% of specimens.

K.Maheswari[36] (2011) analyzed 50 specimens by doing manual dissection, corrosion cast and injecting dyes and described trifurcation pattern in 18% of cases. Out of that she observed type1 branching pattern in 12%, type 2 in 4%, type3 in 2% of cases.

Jeremiah et al[49] (2014) studied 100 livers specimens by manual dissection, collected from Anatomy department, University of Nairobi, Kenya.

They observed conventional trifurcation pattern in 49% of cases. Out of that pattern -I in 34% and pattern –II in 15% of cases was noted.

Rajput et al[54] (2014) noticed branching pattern of PV in right lobe of 25 livers by vascular casts and observed trifurcation pattern in 8% (type 1)

Macchiv et al (2015) studied 50 liver vascular casts and 200 CT images. They noticed PV trifurcation in 20% and 10% of cases respectively.

ii) OTHER VARIATIONS

Margaret et al[40] (1990) analyzed color Doppler ultrasound of 18550 patients and observed single trunk in 4 patients. In such cases MPV entered left lobe and gives segmental branches to all segments.

Philippe et al[53] (1994) analyzed helical CTAP of 69 patients and observed the origin of LPV from RAD in 2% of cases.

Akgul et al[1] (2002) analyzed contrast enhanced helical CT images of 585 patients and observed in 0.3% of cases LPV originating from RAD.

Zaferkoc et al[74] (2007) reviewed MDCT images of 1384 patients and observed absence of PV bifurcation in 0.1% and noted quadrification in 0.2%. Quadrification comprise of RAD, LPV, segmental branch to VI, segmental branch to VII.

Susan standring[68] (2008) mentioned the absence of PV bifurcation on rare occasion. In such case PV as single trunk enters into the left lobe after giving segmental branches to right lobe.

Sahoo et al (2014) reported a case of absent portal vein bifurcation which is a very rare variant and the single intra-hepatic portal vein traverses from right to left lobe of liver with decreasing caliber.

Macchiv et al (2015) studied 50 liver vascular casts and 200 CT images. They noted quadrification pattern in 5% of vascular casts.

7. RIGHT BRANCH OF PORTAL VEIN (1st order branch)

A) ORIGIN OF RPV

S.C.Gupta et al[16] (1977) done study by corrosion cast in 85 liver specimens and observed RPV originated from MPV in (75) 88% and was absent or replaced by its branches in (10) 12% of cases.

Yamane T et al[72] (1988) in their corrosion cast study of 25 human livers, found out that RPV was originated from MPV in (20) 80% of cases and absent in (10) 20% of cases .

Arora et al[3] (2003) studied ramification of portal vein in 15 liver specimens by corrosion cast and observed the origin of RPV from MPV in all cases.

Covey et al[11] (2004) studied CT portograph of 200 patients retrospectively and found RPV to be absent in 35% of cases and replaced by branches.

Atasoy and Ozyurek et al[4] (2006) reviewed 200 MDCT images of patients retrospectively and observed the origin of RPV from MPV in 65.5% of cases.

Zaferkoc et al[74] (2007) reviewed MDCT images of 1384 patients and concluded that the RPV originated from MPV in 78%. In remaining cases RPV was absent and replaced by its branches.

Sugo H et al[66] (2007), in a case report observed type 3 pattern of PV. So that right branch was missing here and replaced by its branches

Susan standring[68] (2008) stated that the RPV usually originates from main portal vein. Also mentioned that in 10-15% of cases RPV is absent and replaced by its branches.

Jeremiah et al[49] (2014) studied 100 livers specimens by manual dissection, collected from Anatomy department, University of Nairobi, Kenya. They observed RPV origin from MPV in 51% of cases.

Rajput et al[54] (2014) did study on branching pattern of PV in right lobe of 25 livers by vascular cast. They observed that RPV originates from main portal vein in 92% of cases. In 8% of cases RPV was absent and replaced by its branches.

B) LENGTH OF RPV

S.C.Gupta et al[16] (1977) did study in 85 liver specimens by corrosion cast and noticed the length of right portal vein between 0.5 -2.0cm.

Arora et al[3] (2003) studied branching pattern of portal vein in 15 liver specimens by corrosion cast and observed the length of RPV ranged 1.3-2.3 cm.

Susan standring[68] (2008) quoted that the length of PV is 2-3cm.

Jeremiah et al[49] (2014) dissected 100 livers specimens taken from Anatomy department, University of Nairobi, Kenya and observed the length of right branch of portal vein was 0.5 cm to 4 cm.

Rajput et al[54] (2014) studied branching pattern of PV in right lobe by vascular casts in 25 livers. The length of the right portal vein observed was 0.5 to 1.8 cm (1.2 cm).

C) MODE OF TERMINATION OF RPV

W.Henry Hollinshead[20] (1976) quoted that RPV has caudate, anterior and posterior branches.

S.C.Gupta et al[16] (1977) done study in 85 liver specimens by corrosion cast and noticed that RPV divides into anterior and posterior branches in (75) 88% of cases. In the remaining (10) 12% of cases its branches originated directly from MPV.

Arora et al[3] (2003) studied ramification of portal vein in 15 liver specimens by corrosion cast and observed that the RPV divides into RAD and RPD in all cases.

Atasoy and Ozyurek et al[4] (2006) reviewed 200 MDCT images of patients retrospectively. They observed the classical bifurcation pattern of RPV in 83.2% (109 out of 131) of patients. 16.8% (22 out of 131) had variant anatomy, out of that 12.2% (16 out of 131) had RPV trifurcation

Zaferkoc et al[74] (2007) reviewed MDCT images of 1384 patients and concluded that the RPV had classical bifurcation pattern in 96.1% (1045 out of 1087) of cases. RPV trifurcation was observed in (3 out of 1087) 0.2% of cases. Separate origin of segment VI and VII portal branch was observed to be originated from RPV in 2.4% (26 out of 1087) and 0.6% (07 out of 1087) respectively.

Susan standring[68] (2008) said variations are common in right portal vein and usually divides into right anterior and right posterior division.

Jeremiah et al [49] (2014) by manual dissection of 100 liver specimens observed bifurcation branching pattern in (31 out of 51) 61% of cases, trifurcation pattern in (11 out of 51) 20.8%, quadrification pattern in (9 out of) 18.2%.

Rajput et al[54] (2014) studied ramification pattern of portal vein in right lobe by vascular casts in 25 livers. They observed second order branches - the right anterior portal vein & right posterior portal vein (classical bifurcation) in 87 % of the cases. In rest 13 % of cases trifurcation pattern (RPD, antero-superior and antero-inferior) was observed.

8. RIGHT ANTERIOR DIVISION (2nd order branch)

A) ORIGIN OF RAD

S.C.Gupta et al[16] (1977) quoted that RAD aroused from RPV in (75) 88% of specimens taken for study using corrosion cast technique. In (10) 12% of cases RAD originated directly from MPV.

Arora et al[3] (2003) studied ramification of portal vein in 15 liver specimens by corrosion cast and observed the origin of RAD from MPV in all cases.

Zaferkoc et al[74] (2007) reviewed MDCT images of 1384 patients and concluded that the RAD originates from RPV in 78%. In 21% of cases RAD arises from main portal vein

Sugo H et al[66] (2007), in a case report observed RAD arising from LPV.

Susan standring[68] (2008) said that RAD arises usually from RPV and in 10-15% of cases it arises from MPV. Occasionally RAD may arise from LPV which is an important variant to be remembered while doing left sided resection.

Rajput et al[54] (2014) studied ramification pattern by vascular casts in 25 livers and observed that RAD originates from RPV in 92% and from main portal vein in 8%.

B) MODE OF TERMINATION OF RAD

S.C.Gupta et al[16] (1977) quoted that RAD divided into superior (supplies segment 8) and inferior branches (supplies segment 5) in all 85 specimens taken for study using corrosion cast technique.

Arora et al[3] (2003) studied ramification of portal vein in 15 liver specimens by corrosion cast and observed RAD divided into superior and inferior branches in all cases. They also observed that antero-superior branch

(s8) ramified as single trunk in 60%. In 40% of cases divided into anterior and posterior branches.

Susan standring[68] (2008) quoted that RAD usually divides into superior and inferior branches and gives branch to caudate lobe occasionally

Rajput et al[54] studied ramification pattern by vascular casts in 25 livers and observed that RAD originates from RPV in 92% and from main portal vein in 8%. RAD divided intoantero-superior (s8) and antero-inferior branch.

9. RIGHT POSTERIOR DIVISION (2nd order branch)

A) ORIGIN OF RPD

S.C.Gupta et al[16] (1977) quoted that RPD aroused directly from RPV in 88% and from MPV in 12% of specimens. RPD divide into superior (supplies segment 7) and inferior branches (supplies segment 6) in all specimens (85) taken for study by corrosion cast.

Arora et al[3] (2003) studied ramification of portal vein in 15 liver specimens by corrosion cast and observed the origin of RPD from RPV in all cases.

Susan standring[68] said that RPD arises usually from RPV and in 10-15% of cases it arises from MPV.

Rajput et al[54] studied ramification pattern of portal vein in right lobe by vascular casts in 25 livers. They observed that RPD originated from RPV in 87% of cases and in rest 13 % of cases, RPD replaced by its branches.

Jeremiah et al[49] (2014) studied 100 livers specimens by manual dissection, collected from Anatomy department, University of Nairobi, Kenya. They observed RPD originated from RPV in 42%, from MPV in 34%, from common LPV in 15 cases.

B) MODE OF TERMINATION OF RPD

S.C.Gupta et al[16] (1977) quoted that RPD divided into superior (supplies segment 7) and inferior branches (supplies segment 6) in all 85 specimens taken for study using corrosion cast technique.

Arora et al[3] 2003 studied 15 liver specimens by corrosion cast and explained that RPD terminated by 3 pattern. The most common type was bifurcation after giving an inferior branch (9 out of 15 specimens) in 60%. The other mode of termination were trifurcation (3 out of 15, 20%, postero-superior, postero-inferior and intermediate branch) and bifurcation (3 out of 15) 20% into superior and inferior branch.

Susan standring[68] (2008) quoted that RPD usually divides into superior and inferior branches and gives branch to caudate lobe occasionally

Rajput et al[54] studied ramification pattern of portal vein in right lobe by vascular casts in 25 livers. They observed that RPD ramified in 3 patterns – type 1, fan second in 64%, type 2 in 28% and type 3 (trifurcation) in 8%.

10. LEFT BRANCH OF PORTAL VEIN (1ST order branch)

A) ORIGIN OF LPV

Couinaud[9] (1952) studied 103 liver specimens by cast and noticed that the LPV originated from MPV in all specimens.

Healey[19] (1954) studied 25 liver specimens by dissection and observed that the LPV originated from MPV in all specimens.

W.Henry Hollinshead[20] said that LPV arises from MPV.

Margaret et al[40] (1990) analyzed color Doppler ultrasound of 18550 patients and found that the LPV usually originated from main portal vein

S.C.Gupta et al[16] (1997) done study by corrosion cast in 85 liver specimens and observed the origin of LPV from MPV in all specimens.

Susan standring[68] stated that the LPV usually originates from main portal vein.

K.Maheswari[37] (2015) did study in 50 liver specimens by doing manual dissection, corrosion cast and injecting dyes. She noticed the origin of LPV from MPV in all specimens.

B) LENGTH OF LPV

Michel N[44] (1955) stated that the length of left portal vein varies between2-4cm.

S.C.Gupta et al[16] (1997) analyzed corrosion cast study of 85 liver specimens and observed the length between1-5 cm.

Susan standring[68] stated that the length of LPV (extra-hepatic part) is 4-5cm.

K.Maheswari[37] **(2015)** studied 50 liver specimens by doing manual dissection, corrosion cast and injecting dyes. She observed that the length of LPV varied from 2-4cm.

C) MODE OF TERMINATION OF LPV

Couinaud[9] **(1952)** studied 103 liver specimens by cast and noticed the absence of horizontal segment of LPV in 1specimen (0.97%).

Healey[19] **(1954)** studied 25 liver specimens by dissection and observed that the LPV has single trunk and two parts-transverse portion (PT) and vertical portion (PU) with a sharp kink in between.

Margaret et al[40] **(1990)** analyzed color Doppler ultrasound of 18550 patients and found PT segment of LPV to be absent in 7 cases.

W.Henry Hollinshead[20] said that LPV has 2 parts. One is PT providing caudate branches. The other one is pars umbilicalis providing medial and lateral rami, then into superior and inferior producing sub-segments

S.C.Gupta et al[16] **(1997)** done study by corrosion cast in 85 liver specimens and observed similar presentation of single trunk and 2 parts. The lateral superior branch aroused from left side of kink in 69%, from PT near the kink in 16%, from left side of PU near the kink in 14%. The lateral inferior branch originated from PU in all specimens.

Susan standring[68] said that it consists of horizontal and vertical parts. The horizontal part (PT, extra-hepatic part) gives branch to caudate lobe and occasionally to quadrate lobe and continues laterally to supply segment II (lateral inferior branch). The main vein takes vertical course (intra-hepatic part, PU) and supplies segment III and IV.

K.Maheswari[36] **(2011)** studied 50 liver specimens by doing manual dissection, corrosion cast and injecting dyes. She observed the LPV to have single trunk and 2 parts. The lateral superior branch aroused from left side of kink in 63.8%, from PT near the kink in 21.3%%, from left side of PU near the kink in 14.9%. The lateral inferior branch originated from PU in all specimens.

Mukesh K. Yadav et al[48] **(2012**) revealed a case report in which the left portal vein continued as inverted v shaped vessel and supplied segment VIII in addition to its usual branches. RAD supplied only segment 5.

11. BRANCH TO CAUDATE LOBE

S.C.Gupta et al[16] **(1977)** analyzed corrosion cast of 85 liver specimens. In all cases the left portion of the caudate lobe receives its blood supply from PT (LPV) and right portion of caudate lobe gets its blood supply from PT in 68%, RPV in14%, MPV in 18%

Scheele[63] **(1994)** mentioned that the right portion of caudate lobe receives portal supply from right portal branch or from bifurcation of MPV whereas left portion receives portal supply from the left branch of portal vein.

Kogure et al[31] (1999) dissected 88 liver specimens and mentioned left portion of caudate lobe receives its main blood supply from LPV (85.8%). He also quoted that the right portion of caudate lobe receives its blood supply from LPV/RPV/from main trunk/bifurcation

Susan standring[68] said that PT of LPV gives branch to caudate lobe. RAD gives branch to segment I occasionally.

K.Maheswari[37] (2015) studied 50 liver specimens by doing manual dissection, corrosion cast and injecting dyes. The left portion receives its blood supply from PT (LPV) in all specimens. The right portion receives its blood supply from PT in 63.8%, RPV in8.5%, MPV in 27.7%

12. BRANCH TO QUADRATE LOBE

S.C.Gupta et al[16] (1997) observed corrosion cast studies of 85 specimens and mentioned that the medial segmental veins supplying quadrate lobe comes from right side of PU in 100%.

Susan standring[68] (2008) mentioned that quadrate lobe receives its main blood supply from LPV and occasionally from RPV, right antero superior and right antero inferior division.

K.Maheswari[37] (2015) studied 50 liver specimens by doing manual dissection, corrosion cast and injecting dyes. She observed that the quadrate lobe received its portal supply from medial branch of PU of LPV. In addition it received an accessory branch from RAD in 4 specimens.

13. ACCESSORY BRANCHES

MostafaAtri[46](1992) described accessory branch to right posterior segment from MPV after analyzing USG images of 507 patients.

Van Leeuween[69] (1994) studied branching pattern of PV in 10 healthy volunteers by MRI procedure and observed accessory branch from RPV in 6 subjects. He also observed double supply to segment 3.

K.Maheswari[36] (2011) studied 50 liver specimens by doing manual dissection, corrosion cast and injecting dyes. She observed accessory branches to right posterior segment from main portal vein in 1 specimen and from right portal vein in 3 specimens. She also observed accessory branches to segment III from pars umbilicalis of LPV in 3 specimens.

14. RELATIONS OF PORTAL VEIN WITH HEPATIC VEIN

Melnikoff (1924) done an extensive study in 111 specimens by injecting plaster of paris and reported that both the venous system were interdigitated and substantiated in their branches.

W.HenryHollinshead[20] (1976) quoted that LHV lies between medial and lateral segments of left lobe. RHV lies between anterior and posterior segments of right lobe. MHV lies between the physiological right and left lobe. Usually LHV and MHV join together and then open into IVC. Sometimes all the three opens independently.

Van Leeuwen[69] (1994), done MRI procedure in 10 healthy volunteers, observed RHV between RAD and RPD, MHV between the 2 branches of MPV and LHV between the LSB and LIB portal branches.

Susan standring[68] (2008) quoted that right hepatic vein lies between right medial and right lateral sectors, left hepatic vein lies between left medial and left lateral sectors, middle hepatic vein lies between right medial and left medial sectors.

K.Maheswari[36] (2011) carried study in 50 specimens by doing manual dissection, corrosion cast and injecting dyes and observed right hepatic vein between right anterior and right posterior segments, middle hepatic vein between right and left branch of portal vein, left hepatic vein between 2nd and 3rd segments of liver.

EMBRYOLOGY

The adult Portal Vein develops from 2principal visceral veins namely the vitelline or omphalomesenteric vein (2 in number) and the umbilical vein (2 in number) - the right and the left, during 4^{th} to 10^{th} week of intrauterine life.

The vitelline veins brings the blood from the yolksac (which becomes the alimentary canal), occupy the splanchnopleure, forms longitudinal channels, ascends run through the Septum transversum, skirt the margins of anterior intestinal portal, lies adjacent to the developing liver and then opens into Cardiac sinus venosus in its posterior aspect.

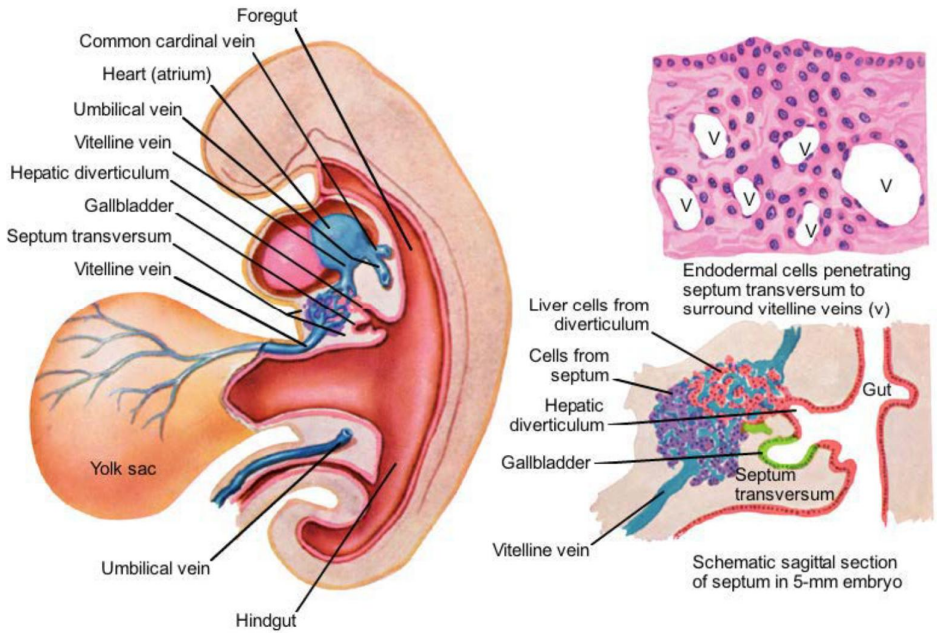
The umbilical vein brings the oxygenated blood from the placenta, occupy somatopleure layer, ascends, run through the Septum transversum, lies on either side of developing liver bud and opens into cardiac sinus venosus. When the liver grows in bulk, it fuses with the lateral body wall.

All these four Veins are interrupted by the developing liver bud. As a result the vitelline veins are subdivided into three parts namely infra-hepatic, intra-hepatic and supra- hepatic.

The intra-hepatic part of vitelline and umbilical veins breaks down to maze of small channels and forms capillary plexus throughout the substance of liver. Then communication with capillary plexus of septal mesenchyme is established under the influence of developing hepatic sheets. Due to changes in the gut and rapid hepatic expansion, the anastomoses become closely interlocked. Later the capillary plexus changes into wider, irregular sinusoidal

vessels. Thus the hepatic sinusoids are formed. So the umbilical vein pours its blood into the liver sinusoids.

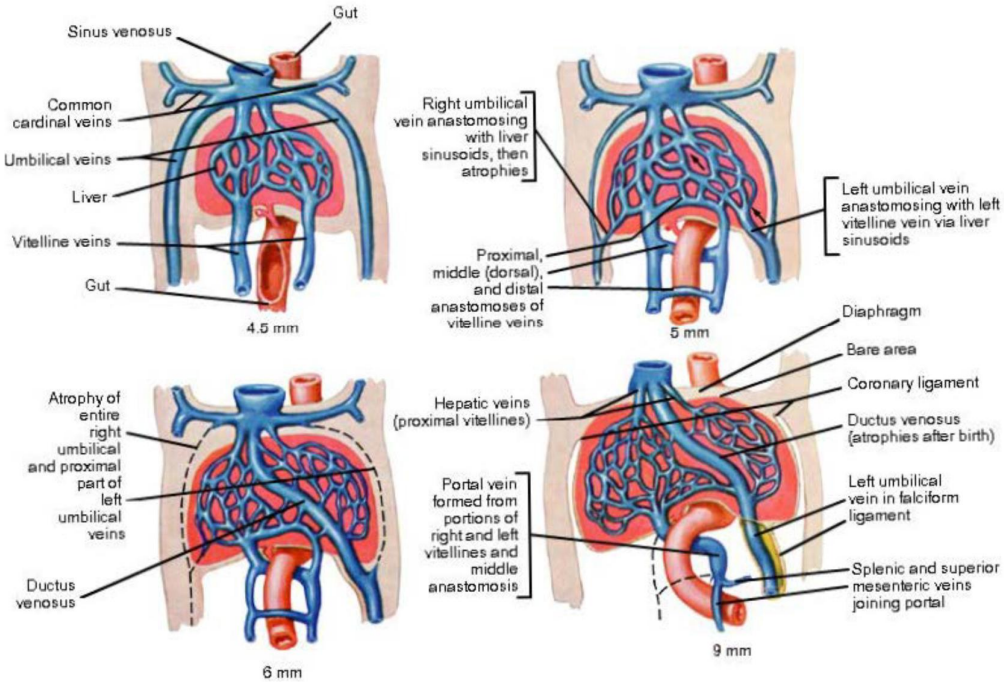
Early Embryo showing development of Vitelline and Umbilical Vein



Hepatic terminal of vitelline and umbilical vein forms afferent and efferent vessels. The afferent vessels known as venae advehentes remains as intra hepatic branches of portal vein. The efferent vessels known as venae readvehentes remains as tributaries of hepatic vein.

The infra-hepatic part of vitelline vein around the presumptive duodenum forms three inter-transverse anastomoses. They are ventral (sub-hepatic), middle dorsal and caudal ventral. Splenic vein opens into left vitelline vein just caudal to middle anastomosis. Due to rotation of stomach and duodenum, the venous circles encircling 1st and 3rd part of duodenum resemble the figure 8.

Development of Portal Vein



The spiral course of definitive hepatic portal vein (trunk) is due to dropping out of original right channel posterior to middle anastomosis and dropping out of original left channel anterior to middle anastomosis. The anterior limb of lower venous circle persists as superior mesenteric vein in front of 3rd part of duodenum. Both superior mesenteric and splenic vein join to form the root of definitive hepatic portal vein. . The part of the right vitelline vein proximal to sub-hepatic anastomosis forms right branch of portal vein. The sub-hepatic anastomosis and the part of left vitelline vein proximal to it forms left branch of portal vein. Subsequently the development of portal radicles and tributaries takes place.

The right umbilical vein disappears completely. The left umbilical vein establish new connection with left branch of portal vein in porta hepatis.

Meanwhile a median longitudinal channel connecting sub-hepatic and sub-diaphragmatic (right half) anastomoses develops called ductus venosus directing the blood form left umbilical vein to inferior vena cava. After birth ductus venosus and left umbilical vein obliterates to form a fibrous cord structure namely ligamentum venosum and ligamentum teres hepatis respectively. Both are attached to left branch of portal vein.

Finally it is understood that the portal vein is formed from vitelline veins by selective involution of bridging anastomoses around duodenum. Any alterations in the obliteration pattern results in several variations.

MATERIALS AND METHODS

STUDY MATERIALS

1. 25 adult Liver specimens
2. 25 contrast enhanced CT (computed tomography) abdomen films.

METHOD OF STUDY

1. Conventional dissection method
2. Radiological study

SPECIMEN COLLECTION

1) 25 adult liver specimens were obtained from the embalmed Cadavers allotted for routine academic dissections to the first year MBBS students in the Institute of Anatomy , Madras Medical College

2) 25 contrast enhanced CT (computed tomography) abdomen films taken during portal phase were collected from archives of Barnard Institute of Radiology, Madras Medical College and RGGGH, Chennai.

CONVENTIONAL DISSECTION METHOD

Abdomen was opened by midline incision and the cavity was exposed by incising the layers of anterior abdominal wall including parietal peritoneum. Greater omentum was identified and lifted. Liver was pulled superiorly. Its

inferior margin was tilted anteriorly to expose the lesser omentum. Structure in the lesser omentum was traced close to the lesser curvature of stomach. Right gastric vein was traced to the portal vein.

Hepatic artery and bile duct was displaced and the portal vein was exposed till the porta hepatis. Stomach was mobilized to the left. Small intestine was turned to the right and left to explore the inferior mesenteric vein and superior mesenteric vein respectively.

The peritoneum and the fat were removed along the right side of 2^{nd}, 3^{rd} and 4^{th} part of duodenum. Inferior mesenteric vein and superior mesenteric vein were traced upwards. Tail of the pancreas was lifted from the spleen and the body was separated from the posterior abdominal wall.

Splenic vein was traced to its junction with Superior mesenteric vein. Thus the portal vein trunk was identified, traced upwards and its division at porta hepatis was noted.

Liver was pulled downwards and removed after cutting the falciform ligament, coronary ligaments, triangular ligaments, inferior vena cava, portal vein, hepatic duct and hepatic artery.

25 liver specimens were removed and preserved in 10% formalin solution .The 25 liver specimens were dissected manually and all the branching pattern of portal vein were observed. All the previous mentioned parameters were studied and noted in all specimens.

RADIOLOGICAL STUDY

25 contrast enhanced CT (computed tomography) abdomen films taken during portal phase were collected from archives of Barnard Institute of Radiology Madras Medical College and RGGGH. Portal vein branching pattern and variations were observed.

OBSERVATION

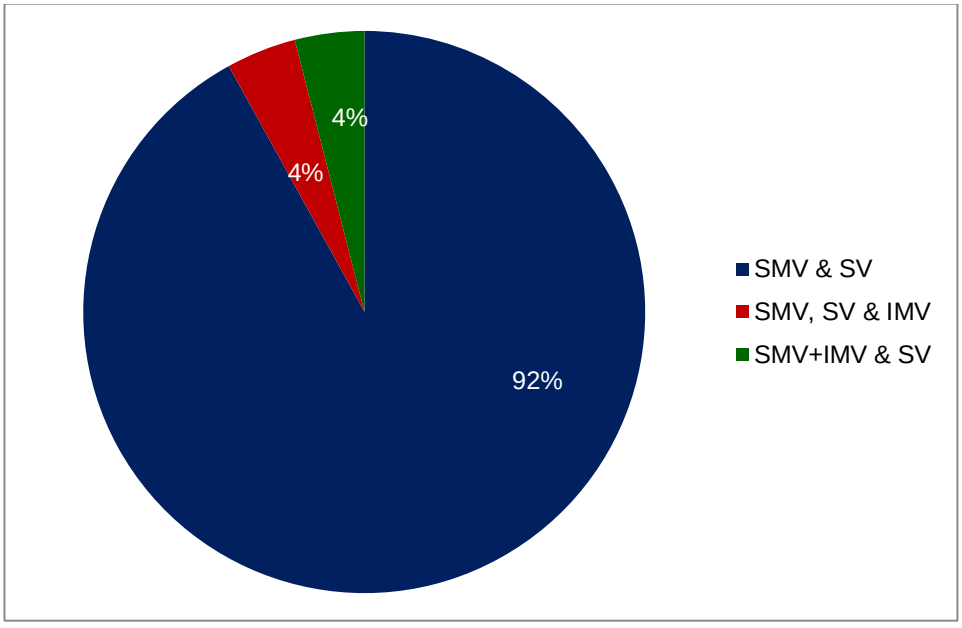
1. PORTAL VEIN FORMATION

Out of dissection of 25 cadavers, PV was formed by the union of SMV and SV in 23 cases (92%) fig.1(a). In 1(4%) case PV was formed by the union of SMV, SV and IMV fig 1 (c). In another 1(4%) case PV was formed by the union of SMV and SV, here the IMV ends in SMV fig 1 (b).

Table1: Formation of PV

Tributaries of PV	Frequency	Percentage
SMV & SV	23	92%
SMV, SV & IMV	1	4%
SMV+IMV & SV	1	4%

Chart1: Formation of PV



2. LEVEL OF FORMATION

Out of dissection of 25 cadavers, PV was formed at the L2 vertebral level in all the cases.

3. LENGTH OF PORTAL VEIN

The observed mean length of portal vein was 7-8 cm in all 25 cadavers taken for dissection.

4. RELATION IN PORTA HEPATIS

The portal vein traced was behind the common bile duct and hepatic artery in all 25 dissected human cadavers fig 2.

5. DIVISION OF PORTAL VEIN

The division of portal vein was extra-hepatic (at porta hepatis) in all 25 dissected human cadavers fig 3.

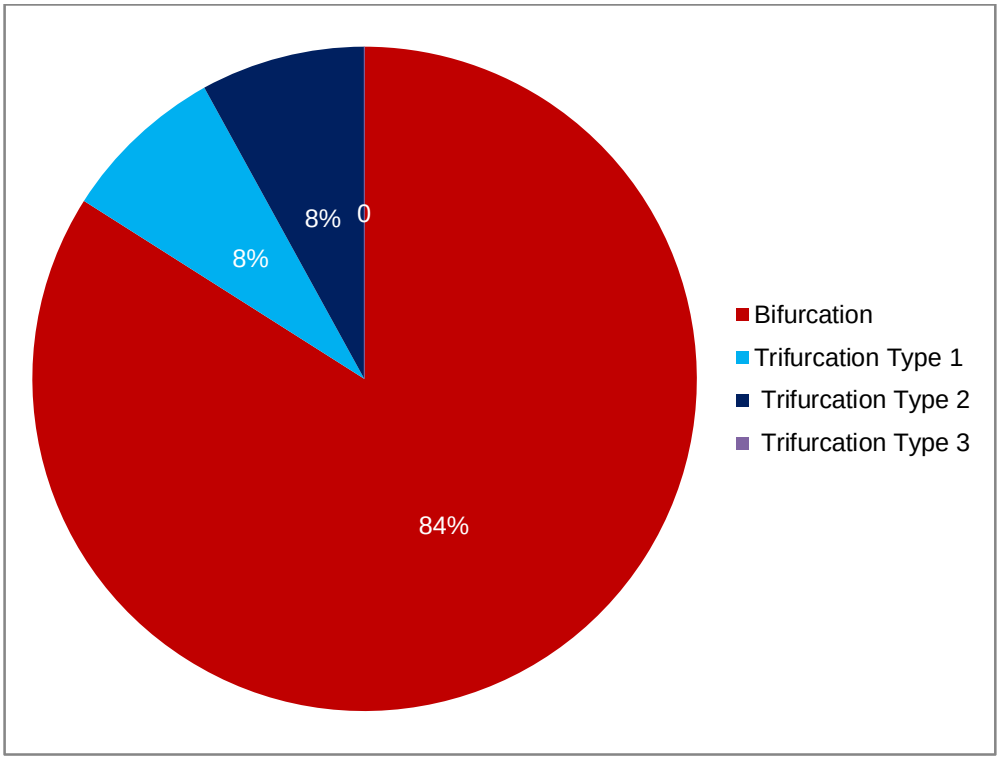
6. BRANCHING PATTERN OF PORTAL VEIN

Out of 25 liver specimens, the portal vein branches into right and left portal vein (Bifurcation) in 21(84%) cases fig 4 and 8. In 2 (8%) specimens the portal vein was divided into right anterior segmental branch, right posterior segmental branch and left portal vein (trifurcation –pattern 1) fig 5 . In 2 (8%) specimens the portal vein gives off right posterior segmental branch first and then divided into right anterior segmental branch and left portal vein (trifurcation –pattern 2) fig 6.

Table 2: Branching pattern of PV

Pattern	Percentage
Bifurcation	84%
Trifurcation	16%
Type 1	8%
Type 2	8%
Type 3	0

Chart 2: Branching pattern of PV

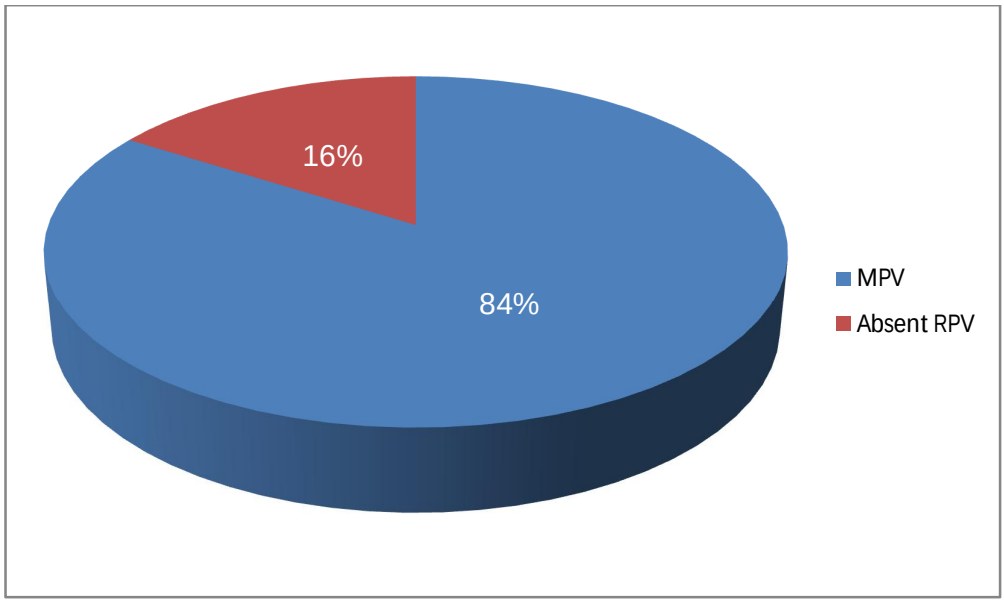


7. RIGHT BRANCH OF PORTAL VEIN (1st order branch) ORIGIN, LENGTH and TERMINATION OF RPV

Table 3: Origin of RPV

Origin	Frequency	Percentage
MPV	21	84%
Absent RPV	4	16%

Chart 3: Origin of RPV



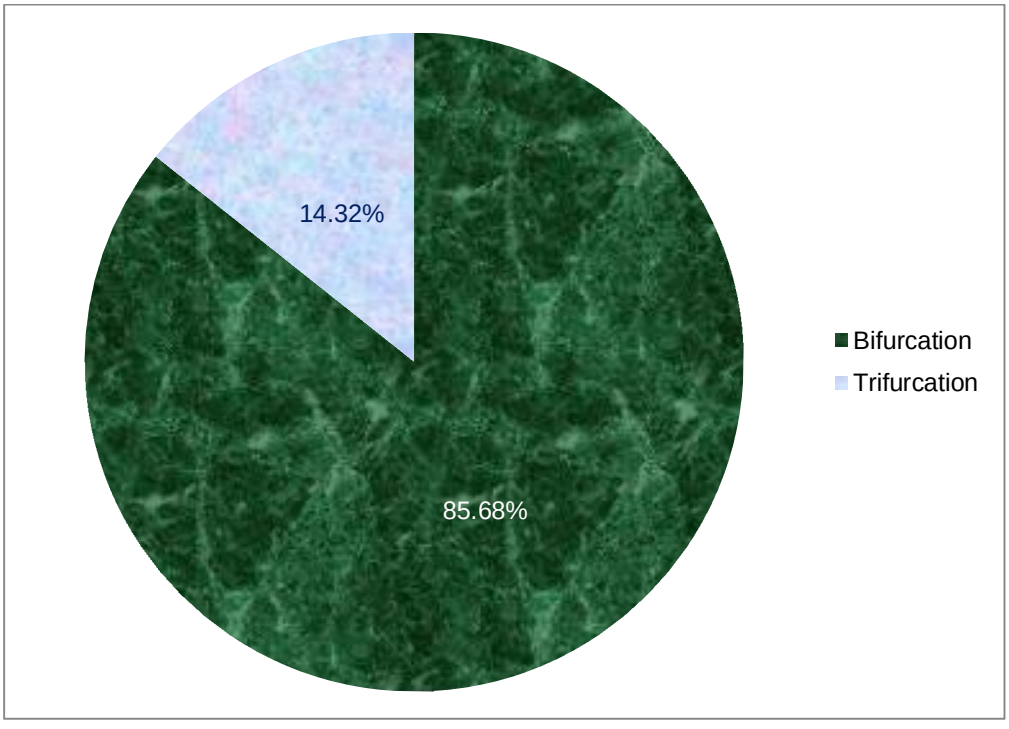
Out of 25 liver specimens dissected in order to know the intra-hepatic branching pattern of PV, it was observed that the right branch of portal vein originated from MPV in 84% (21) of cases and was absent in 16% (4) of cases. The mean length of RPV observed was 0.5 -2.0 cm.

The RPV was divided into two branches – the right anterior and posterior branch in 85.68% (18) of specimens fig7. In 14.32% (3) of specimens it was ramified into 3 branches – RAD, right postero superior and right antero inferior fig 17.

Table 4: Mode of Termination of RPV

Pattern	Frequency	Percentage
Bifurcation	18	85.68%
Trifurcation	3	14.32%

Chart 4: Mode of Termination of RPV



8. RIGHT ANTERIOR DIVISION (2nd order branch)

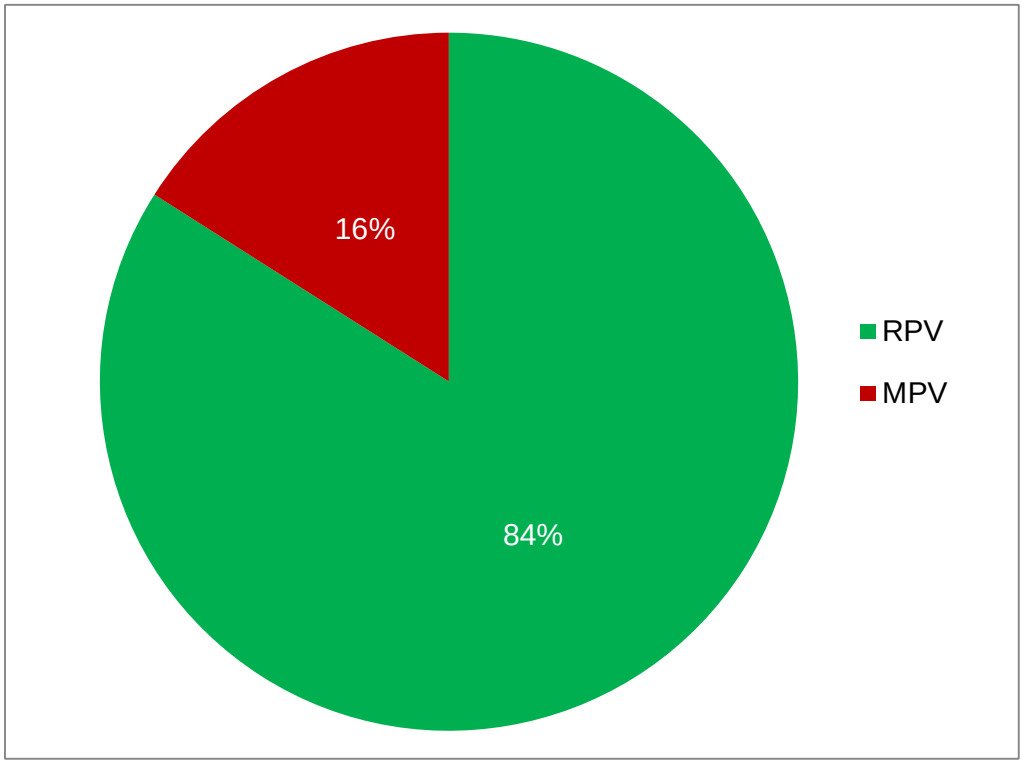
ORIGIN AND MODE OF TERMINATION OF RAD

RAD originated from RPV in (21) 84% of cases. In dissection of remaining 4 specimens it was observed that RAD originated directly from MPV. In all 25 specimens taken for study RAD divided into anterosuperior and antero inferior branches.

Table 5: Origin of RAD

Origin	Frequency	Percentage
RPV	21	84%
MPV	4	16%

Chart 5: Origin of RAD



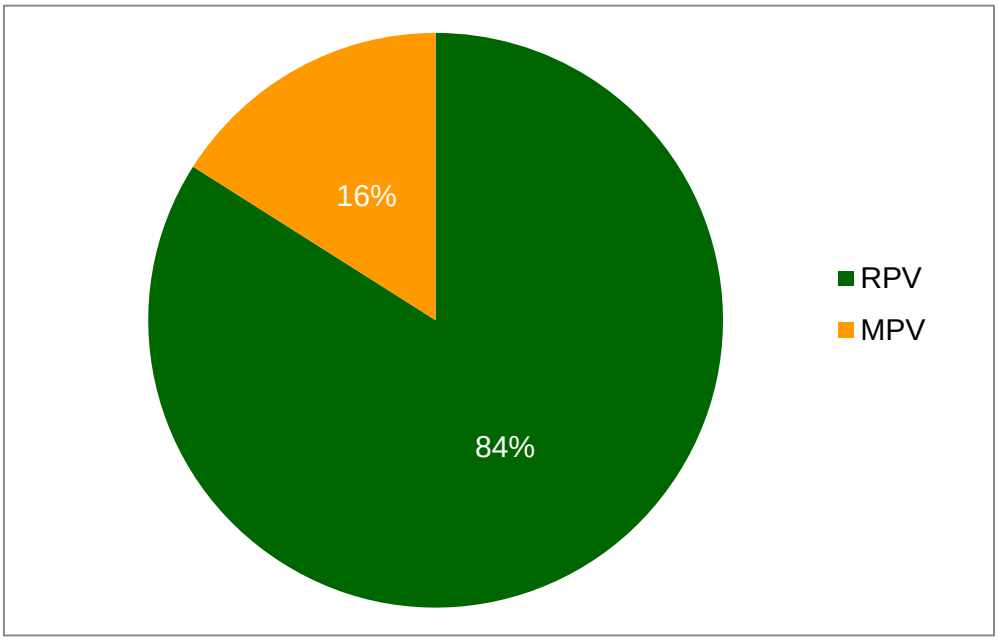
9. RIGHT POSTERIOR DIVISION (2nd order branch)

ORIGIN AND TERMINATION OF RPD

Table 6: Origin of RPD

Origin	Frequency	Percentage
RPV	21	84%
MPV	4	16%

Chart 6: Origin of RPD



In 25 liver specimens dissected, RPD originated from RPV in 21 and from MPV in 4 specimens. The usual branches of RPD were observed in all specimens fig 7.

10. LEFT BRANCH OF PORTAL VEIN (1ST order branch)

ORIGIN, LENGTH AND MODE OF TERMINATION

LPV originated from MPV in all 25 specimens. In all specimens LPV has 2 parts. The length of LPV (extra-hepatic,i.e.horizontal part/PT) was between 2-5cm and observed to be terminated by giving LSB, LIB, medial branches and branch to caudate lobe in all cases taken for study fig 9. Accessory branch to segment III was observed from pars umbilicalis in 3 specimens.

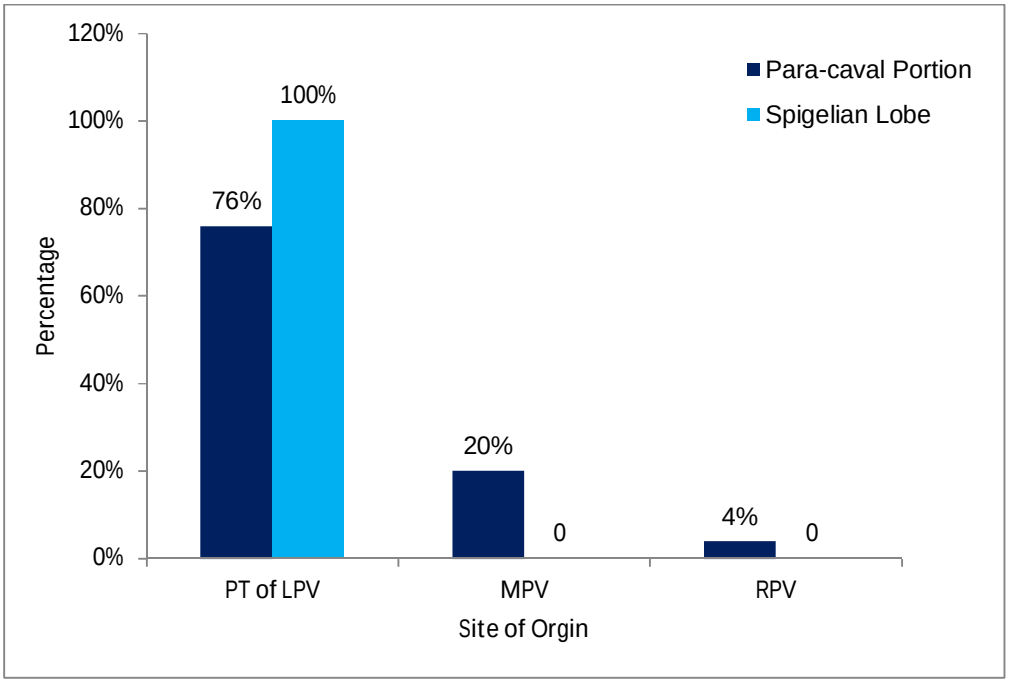
11. BRANCH TO CAUDATE LOBE

The left part of caudate lobe received its portal supply from PT of LPV in all 25 specimens taken for study. The right portion received its supply from PT of LPV in 76%, from portal trunk in 20%, from RPV in 4%.fig 10.

Table 7: Branch to Caudate Lobe

Site of Origin	Para-caval Portion	Spigelian Lobe
PT of LPV	76%	100%
MPV	20%	Nil
RPV	4%	Nil

Chart 7: Branch to Caudate Lobe



12. BRANCH TO QUADRATE LOBE

After dissection of 25 liver specimens, it was observed that quadrate lobe receives 3-5 portal branches from medial side of PU of LPV in all specimens fig 11. In 2 specimens quadrate lobe received accessory branch from RPV fig 13.

13. ACCESSORY BRANCHES

Out of dissection of 25 liver specimens, accessory branch to segment III from left side of PU (LPV) was observed in 3 specimens fig 12. Accessory branch to quadrate lobe from RPV was noticed in 2 specimens fig13. Accessory branch to segment VI from RPD and right postero inferior branch was noticed in 4 specimens fig 14.

14. RELATIONS OF PORTAL VEIN WITH HEPATIC VEIN

In all 25 liver specimens dissected, RHV was observed between RAD and RPD of RPV. MHV was observed between right and left branch of portal vein in all 25 liver specimens. LHV was observed at right angles to lateral superior and lateral inferior branches of LPV in all specimens fig 15 and 16.

RADIOLOGICAL STUDY

25 adult CT portography

25 adult CT portography films were collected from archives of Barnard Institute of Radiology and branching pattern of portal vein were studied.

In all CT images the PV was formed by the union of SMV and SV.

In all 25 cases portal vein divided into right branch and left branch. The right branch was bifurcated into RAD and RPD in all cases. RAD and RPD both divided into superior and inferior branches.

In all 25 cases the left branch was observed to give rise to LSB, LIB, branches to caudate and quadrate lobe.

In all images RHV, LHV and MHV was observed in their usual position in relation to portal vein as documented in literature.

DISCUSSION

PORTAL VEIN FORMATION

G.J.Romanes (1972), **Susan standring (2008)**, **Keith L Moore (2010)**, **S.chummy sinnatamby (2011)** mentioned that portal vein is formed by union of SMV and SV.

W.Henry Hollinshead (1976), **John V.Basmajian (1979), Keith L Moore (2010)** quoted that the portal vein can also be formed by the union of SV, SMV and IMV behind the neck of pancreas.

In the **present study**, portal vein was formed by the union of SMV and SV in 23 cases (92%). In 1 case all the three confluences together in the formation of portal vein. In 1 case IMV drained into SMV.

Double portal vein, absent PV, accessory portal vein, anomalous formation of PV, Pre-duodenal portal vein and pre-pancreatic post duodenal portal vein had been reported in literature.

In the **present study**, no such cases were seen, as all was a rare variant.

The knowledge on formation and relations are important for both surgeons and radiologists. Any variations results in confusion during radiological and surgical procedures.

Knowing these variations are useful in treating traumatic rupture of the mesentery, surgeries of pancreas, duodenum and management of venous thrombosis as it mainly occurs in portal vein and superior mesenteric vein.

LEVEL OF FORMATION

Susan standring (2008), Neeta V Kulkarni (2012) quoted that it starts at the level of L2 vertebra.

Keith L Moore (2010) mentioned that PV arises at the level of L1 vertebra.

In the **present study** portal vein formation taken place at L2 vertebra.

LENGTH OF PORTAL VEIN

G.J.Romanes (1972), **Susan standring (2008)**, **Keith L moore (2010)**, **S.Sinnatamby Chummy (2011)** , **V Kulkarni (2012), Keith L moore (2010)** all stated that its length averages about 7-8 cm

In the **present study** the length of portal vein averages about 7-8 cm.

RELATION IN PORTA HEPATIS

G.J.Romanes (1972) W.Henry Hollinshead (1976) **John V.Basmajian (1979) Susan standring (2008) S.Sinnatamby Chummy (2011)** all stated that it ascends upwards within the lesser omentum in front of inferior vena cava separated by epiploic foramen and reaches the right end of hilum. At porta hepatis it lies posterior to the CBD and hepatic artery.

S.C.Gupta et al (1997) also substantiated the same in their study

In the **present study** also same relations were noted in all specimens.

DIVISION OF PORTAL VEIN

G.J.Romanes (1972) W.Henry Hollinshead (1976) John V.Basmajian (1979) Susan standring (2008) S.Sinnatamby Chummy (2011) mentioned that the portal vein divides into 2 branches at porta hepatis.

S.C.Gupta et al (1997) stated that division was extra-hepatic in all specimens.

Margaret et al (1990) Zafer koc et al (2007) Susan standring (2008) Sahoo et al (2014) mentioned a rare entity of absent PV bifurcation at porta hepatis and so the single intra-hepatic portal vein

In the **present study** the division of PV was extra-hepatic in all specimens.

Knowing this variation in the hilar portal ligation will prevent hepatic failure and death. Liver transplantation and resection requires portal vein reconstruction, the extra-hepatic division of the portal vein facilitate ligation easy.

BRANCHING PATTERN OF PORTAL VEIN

BIFURCATION OF PV (Standard Anatomy)

Table 8a: Comparison of Portal Vein Branching Pattern

Pattern	Authors		
Types	**Gupta et al (1977)**	**Ortale et al (2000)**	**Present Study**
Bifurcation	88%	78%	84%
Trifurcation	12%	22%	16%

Table 8a: Comparison of branching pattern of portal vein

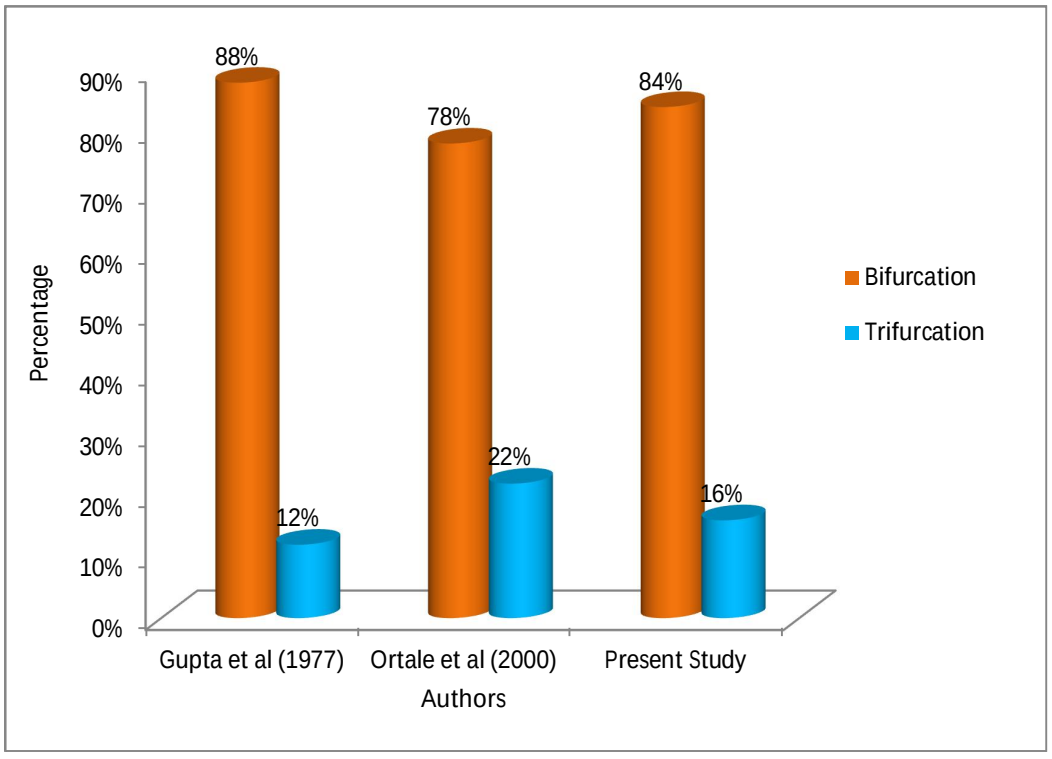
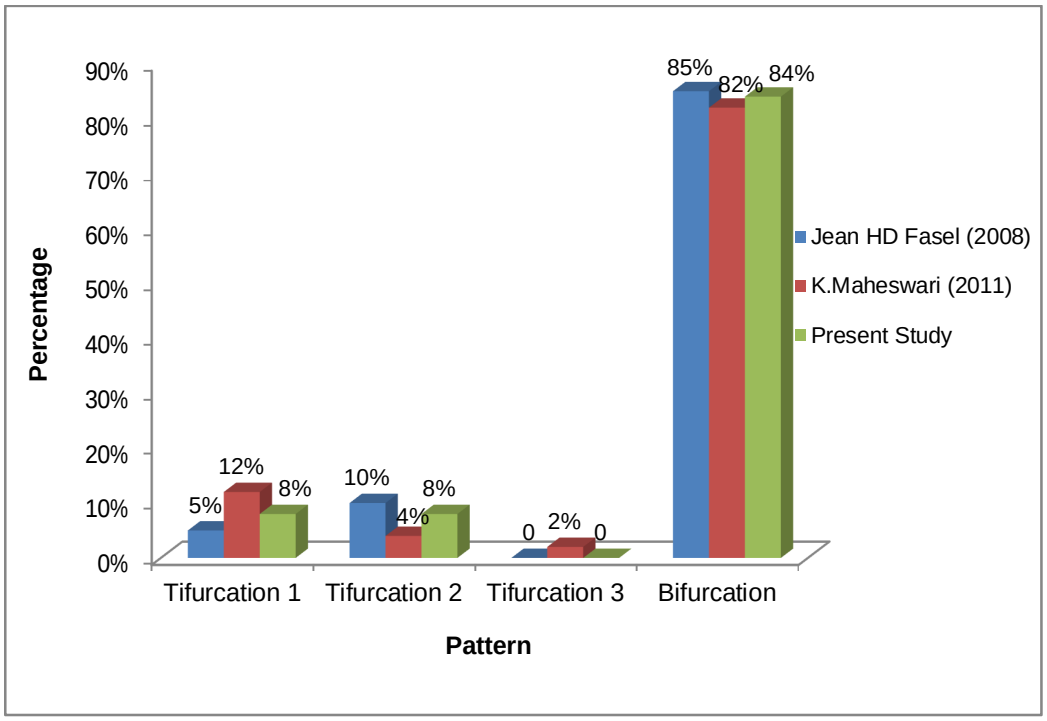


Table 8b: Comparison of PV Branching Pattern

Pattern		Jean HD Fasel (2008)	K.Maheswari(2011)	Present Study
Trifurcation	Type 1	5%	12%	8%
	Type 2	10%	4%	8%
	Type 3	Nil	2%	Nil
Bifurcation		85%	82%	84%

Chart 8b: Comparison of PV Branching Pattern



S.C. Gupta et al (1977) Yamane T et al., (1988) Arora et al., (2003) (25 casts) and Healey (1954) (25 dissection) **Jean H.D.Fasel (2008)** (20 dissection) **and K.Maheswari (2011)** (50 manual dissection, corrosion cast and dye injections) observed normal branching pattern in 80-90% of the cases.

Margaret et al (1990) Mostafa Atri (1992) Philippe et al (1994) Akgul et al., (2002), Covey et al (2004),**Atasoy and Ozyurek et al (2006)** , **Zafer koc et al (2007)** all noticed 2 branches the right and left in 80-95% of cases by analyzing radiological images.

The **present study** resembles the above studies.

But **Jeremiah et al (2014)**, Kenya observed conventional bifurcation pattern in 51% of cases which may be due to ethnic variation.

VARIANT BRANCHING PATTERN

i) TRIFURCATION OF PV

Couinaud (1952) , S.C. Gupta et al (1977) Yamane T et al., (1988), Jean HD Fasel (2008) , **Rajput et al (2014**) , **K.Maheswari (2011)** all observed trifurcation pattern between 15-20% by using dissection or corrosion cast method.

Margaret et al (1990) Mostafa Atri (1992) Akgul et al., (2002) Covey et al (2004) Zafer koc et al (2007) Atasoy and Ozyurek et al (2006) Wu Tc et al (2007) Zafer koc et al (2007) all observed trifurcation pattern between 15-20% by analyzing radiological studies.

Susan standring (2008) said that the prevalence of type 1 branching pattern is 10-15%. So the right branch of PV is absent.

The **present study** showed similar results with trifurcation pattern of about 16%(Type 1-8%, Type 2-8%) which was similar to the above mentioned studies.

Sugo H et al (2007), in a case report observed type 3 branching pattern of PV.. **Susan standring (2008**) also stated that right anterior portal vein may arise occasionally from left portal vein that is type 3 trifurcation pattern of portal vein.

Type 3 trifurcation pattern was not observed in the present study.

ii) OTHER VARIATIONS

Other variations like single trunk, origin of LPV from RAD, quadrification of PV were not observed in the present study.

The most suitable anatomy for right lobe living donor liver transplantation is bifurcation, in which the right anterior portal vein (RAPV) and right posterior portal vein (RPPV) originate from the right portal vein (RPV).

In type 1, type3 trifurcation two portal vein anastomoses are done which increases the risk of postoperative thrombosis. If these branches are closer, reconstruction with the bifurcation of the recipient's portal vein is easily performed.

In PV trifurcation the portal vein puncture site created during a TIPS placement will be acute and difficult to stent.

In case of trifurcation, isolation of the branches was possible only by exposing the parenchyma and the hilar plate (unroofing of the portal vein).

RIGHT BRANCH OF PORTAL VEIN (1st order branch)

i) ORIGIN OF RPV

S.C. Gupta et al (197 Yamane T et al., (1988,) Rajput et al (2014) found out that RPV originated from MPV in a majority of cases.

The **present study** also substantiated the same results.

ii) LENGTH OF RPV

The length of right portal vein observed varies between 0,5 -2.0 cm which correlated with findings of S.C. Gupta et al 1997 , Arora et al., (2003**)**

Table 9: Comparison of Length of RPV

Length	Gupta et al. (1977)	Rajput et al (2014)	Present study
RPV	0.5-2cm	0.5-1.8cm	0.5-2cm

MODE OF TERMINATION OF RPV

Table 10: Mode of Termination of RPV

Pattern	Authors		
	Gupta et al. (1977)	**Rajput et al (2014)**	**Present Study**
Bifurcation	88%	87%	85.68%
Trifurcation	Nil	13%	14.32%

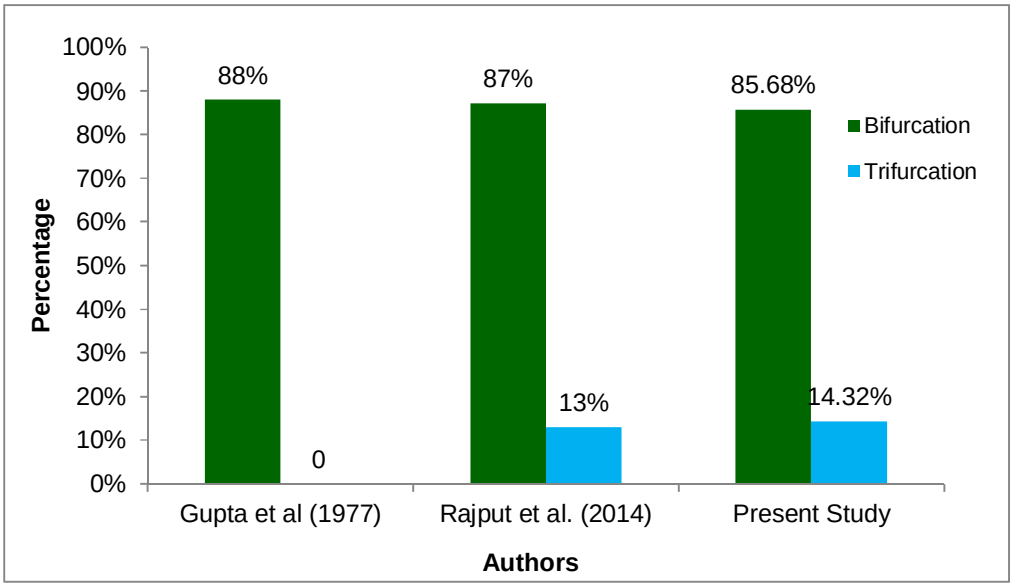
W.Henry hollinshead (1976) quoted that RPV has caudate, anterior and posterior branches.

S.C. Gupta et al (1977) Arora et al., (2003) Susan standring (2008) said variations are common in right portal vein and usually divides into right anterior and right posterior division.

Atasoy and Ozyurek et al (2006)) **Zafer koc et al (2007) Jeremiah Munguti et al (2014) Rajput et al (2014)** observed bifurcation (most common) ,trifurcation branching pattern of right portal vein.

The **present study** closely resembles the above studies with bifurcation of 85.68% (most common) and trifurcation of 14.32%.

Chart 9: Mode of Termination of RPV



RIGHT ANTERIOR DIVISION (2nd order branch)

i) ORIGIN OF RAD

S.C. Gupta (1977) quoted that RAD aroused from RPV in (75) 88% of specimens and in (10) 12% of cases RAD originated from MPV.

Arora et al., (2003) observed the origin of RAD from MPV in all cases.

Zafer koc et al (2007) concluded that the RAD originates from RPV in 78%. In 21% of cases RAD arises from main portal vein

Sugo H et al (2007), in a case report observed RAD arising from LPV.

Susan standring (2008) said that RAD arises usually from RPV and in 10-15% of cases it arises from MPV. Occasionally RAD may arise from LPV which is an important variant to be remembered while doing left sided resection.

Rajput et al (2014) observed that RAD originates from RPV in 92% (23) cases and from main portal vein in 8% (2) cases.

In the **present study,** it was observed that right anterior division originated from right portal vein in 84% of cases which coincides with the findings of Zafer koc et al 2007 (78%), S.C.Gupta et al 1977 (88%), K.Maheswari 2011(82%).

ii) MODE OF TERMINATION OF RAD

S.C. Gupta (1977) quoted that RAD divided into superior (supplies segment 8) and inferior branches (supplies segment 5) in all specimens.

Arora et al. (2003) observed that RAD divided into superior and inferior branches in all cases. They also observed that antero-superior branch (s8) ramified as single trunk in 60%. In 40% of cases divided into anterior and posterior branches.

Susan standring (2008) quoted that RAD usually divides into superior and inferior branches and gives branch to caudate lobe occasionally

Rajput et al (2014) observed that RAD divided into antero-superior (s8) and antero-inferior branch.

In the **present study** right anterior division divided into superior and inferior branches in all specimens which coincides with the above mentioned studies.

RIGHT POSTERIOR DIVISION (2nd order branch)

i) ORIGIN OF RPD

S.C. Gupta (1977) quoted that RPD aroused directly from RPV in 88% and from MPV in 12% of specimens.

Arora et al., (2003) observed the origin of RPD from RPV in all cases.

Susan standring (2008) said that RPD arises usually from RPV and in 10-15% of cases it arises from MPV.

Rajput et al (2014) observed that RPD originated from RPV in 87% of cases and in rest 13 % of cases, RPD replaced by its branches.

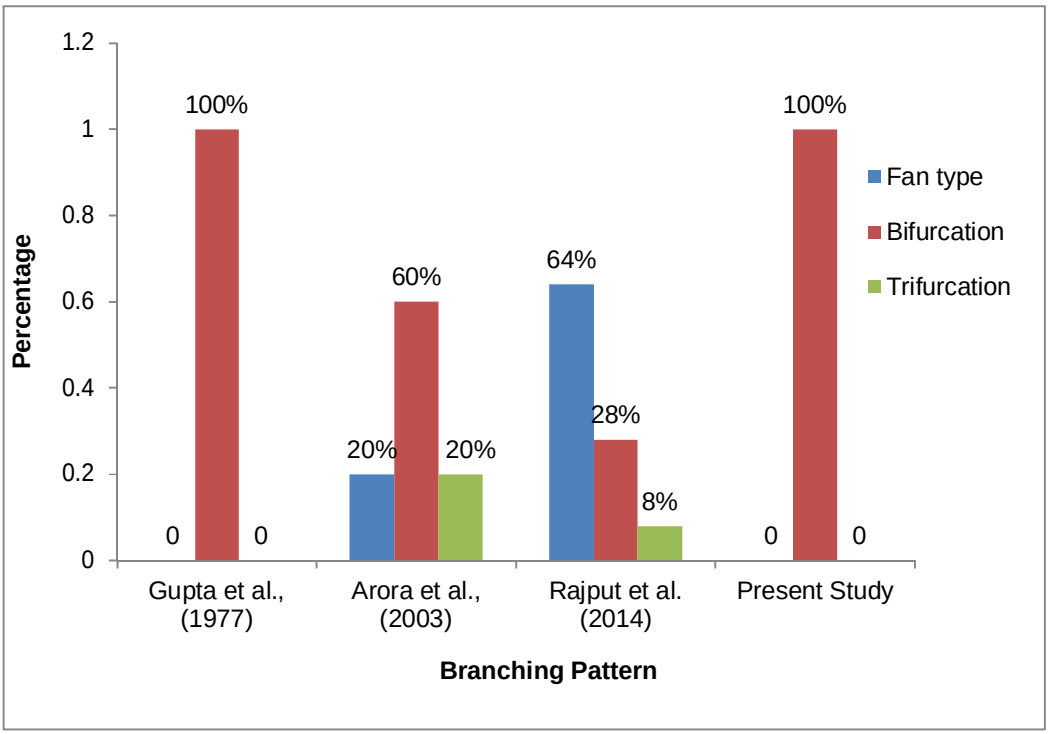
Jeremiah et al (2014) observed RPD originating from RPV in 42%, from MPV in 34%, from common LPV in 15 cases.

In the **present study** RPD originated from RPV in 84% of cases and from MPV in 16% of cases which closely resembles the above study.

Table 12: Mode of termination of RPD

Branching Pattern		**Authors**			
Types		**Gupta et al., (1977)**	**Arora et al. (2003)**	**Rajput et al. (2014)**	**Present Study**
I	Fan type	Nil	20%	64%	Nil
II	Bifurcation	100%(85)	60%	28%	100%(25)
III	Trifurcation	Nil	20%	8%	Nil

Chart 10: Mode of termination of RPD



ii) MODE OF TERMINATION OF RPD

S.C. Gupta (1977) quoted that RPD divided into superior (supplies segment 7) and inferior branches (supplies segment 6) in all 85 specimens taken for study using corrosion cast technique.

Arora et al 2003 explained that RPD terminated by 3 pattern. The most common type was bifurcation after giving an inferior branch (9 out of 15 specimens) in 60%. The other mode of termination were trifurcation (3 out of 15) in 20% (postero-superior, postero-inferior and intermediate branch) and bifurcation (3 out of 15) in 20% into superior and inferior branch.

Susan standring (2008) quoted that RPD usually divides into superior and inferior branches and gives branch to caudate lobe occasionally

Rajput et al (2014) observed that RPD ramified in 3 patterns – type 1, fan second in 64%, type 2 in 28% and type 3 (trifurcation) in 8%.

In the **present study** RPD bifurcates into superior and inferior branches in all specimens. This finding was similar to study done by S.C.Gupta et al (1997).

LEFT BRANCH OF PORTAL VEIN (1ST order branch)

i) ORIGIN OF LPV

Couinaud (1952) Healey (1954) W.Henry hollinshead (1976) Margaret et al.,(1990) Gupta et al (1977)Susan standring (2008), **K.Maheswari (2011**) all mentioned that LPV originates from MPV.

In the **present study** also it was observed that LPV originates from MPV in all specimens which coincides with the above studies.

ii) LENGTH OF LPV

Michel N (1955) stated that the length of left portal vein varies between2-4cm.

Gupta et al (1997) observed the length between1-5 cm.

Susan standring (2008) stated that the length of LPV (extra-hepatic part) is 4-5cm.

K.Maheswari (2015) observed the length of LPV between2-4cm.

In the **present study** the length of LPV was between 2-5 cm.

Table 11: Comparison of Length of LPV

Length	Gupta et al. (1977)	K.Maheshwari (2011)	Present study
LPV	1-5cm	2-4cm	2-5cm

iii) MODE OF TERMINATION OF LPV

Couinaud (1952) noticed the absence of horizontal segment of LPV in 1specimen (0.97%).

Healey (1954) observed that the LPV has single trunk and two parts-transverse portion (PT) and vertical portion (PU) with a sharp kink in between.

Margaret et al., (1990) found PT segment of LPV to be absent in 7 cases.

W.Henry hollinshead (1976) said that LPV has 2 parts. One is PT providing caudate branches. The other one is pars umbilicalis providing medial and lateral rami, then into superior and inferior producing sub-segments

Gupta et al (1997) done study by corrosion cast in 85 liver specimens and observed similar presentation of single trunk and 2 parts. The lateral superior branch aroused from left side of kink in 69%, from PT near the kink in 16%, from left side of PU near the kink in 14%. The lateral inferior branch originated from PU in all specimens.

Susan standring (2008) said that it consists of horizontal and vertical parts. The horizontal part (PT, extra-hepatic part) gives branch to caudate lobe

and occasionally to quadrate lobe and continues laterally to supply segment II (lateral inferior branch). The main vein takes vertical course (intra-hepatic part, PU) and supplies segment III and IV.

K.Maheswari (2011) studied 50 liver specimens by doing manual dissection, corrosion cast and injecting dyes. She observed the LPV to have single trunk and 2 parts. The lateral superior branch aroused from left side of kink in 63.8%, from PT near the kink in 21.3%%, from left side of PU near the kink in 14.9%. The lateral inferior branch originated from PU in all specimens.

Mukesh K. Yadav et al (2012) revealed a case report in which the left portal vein continued as inverted v shaped vessel and supplied segment VIII in addition to its usual branches. RAD supplied only segment 5

In the **present study** the results were similar to above studies like Gupta et al (1997), K.Maheswari (2011).

BRANCH TO CAUDATE LOBE

Gupta et al (1977) analyzed corrosion cast of 85 liver specimens. In all cases the left portion of the caudate lobe receives its blood supply from PT (LPV) and right portion of caudate lobe gets its blood supply from PT in 68%, RPV in14%, MPV in 18%

Scheele (1994) mentioned that the right portion of caudate lobe receives portal supply from right portal branch or from bifurcation of MPV whereas left portion receives portal supply from the left branch of portal vein.

Kogure et al (1999) dissected 88 liver specimens and mentioned left portion of caudate lobe receives its main blood supply from LPV (85.8%). He also quoted that the right portion of caudate lobe receives its blood supply from LPV/RPV/from main trunk/bifurcation

Susan standring (2008) said that PT of LPV gives branch to caudate lobe. RAD gives branch to segment I occasionally.

K.Maheswari (2015) studied 50 liver specimens by doing manual dissection, corrosion cast and injecting dyes. The left portion receives its blood supply from PT (LPV) in all specimens. The right portion receives its blood supply from PT in 63.8%, RPV in8.5%, MPV in 27.7%

The independent portal segmentation within the caudate lobe is important for safe procedures like resections and extended left hepatectomy with the caudate lobe in living donor liver transplantation (LDLT).

Table 13: Comparison of Portal Branches to Caudate Lobe

Site of Origin	Paracaval			Spigelian Lobe		
	Gupta et al (1977)	K.Maheswari (2015)	Present Study	Gupta et al (1977)	K.Maheswari (2015)	Present Study
From RPV	14%	8.5%	4%	Nil	Nil	Nil
From PT of LPV	68%	63.8%	76%	100%	100%	100%

Chart 11a: Comparison of Portal Branches to Caudate Lobe

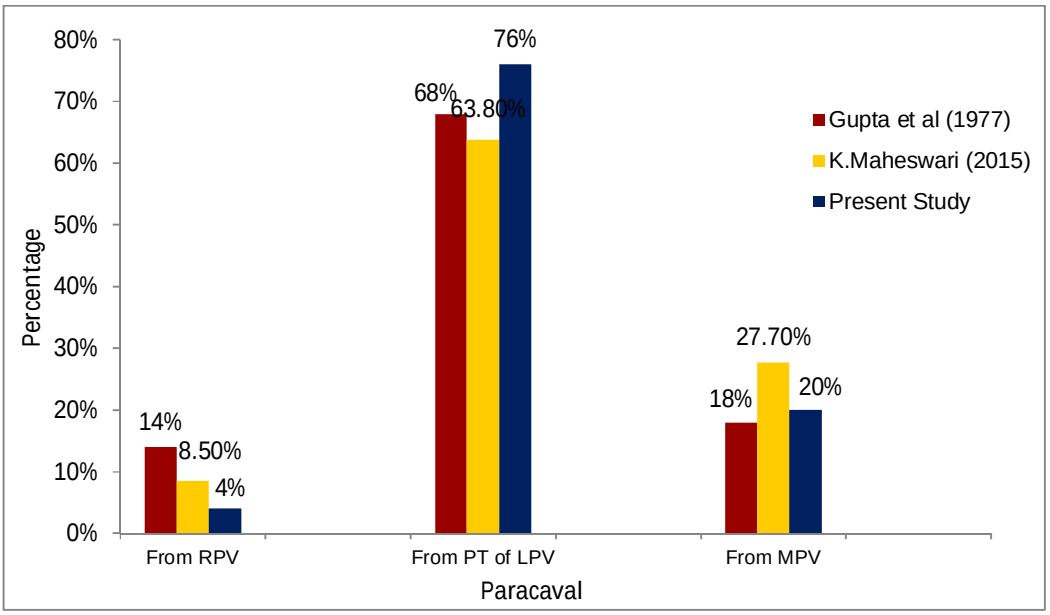
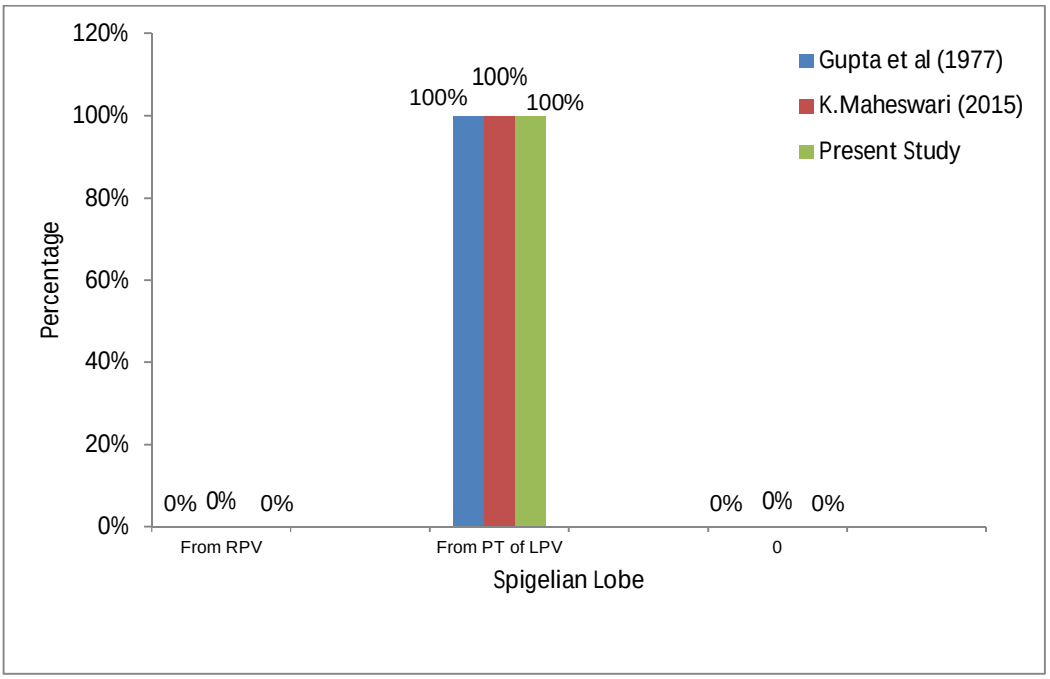


Chart 11 b: Comparison of Portal Branches to Caudate Lobe



BRANCH TO QUADRATE LOBE

S.C.Gupta et al (1997) observed that the medial segmental veins supplying quadrate lobe comes from right side of PU in 100%.

Susan standring (2008) mentioned that quadrate lobe receives its main blood supply from LPV and occasionally from RPV, right antero superior and right antero inferior division.

K.Maheswari (2015) observed that the quadrate lobe received its portal supply from medial branch of PU of LPV. In addition received an accessory branch from RAD in 4 specimens.

In the **present study**, the left part of caudate lobe received its portal supply from Pars transversalis of Left portal vein all 25 specimens taken for study which is comparable to the study done by s.c.Gupta et al, K.Maheswari et al.

The right portion received its supply from Pars transversalis of Left portal vein in 76%, from portal trunk in 20%, from Right portal vein in 4% which is comparable to the study done by S.C.Gupta et al, K.Maheswari et al.

The importance is given to blood supply of segment IV. If it arises from the right dissection is carried only to this branch. If it arise from the left, dissection is carried to the bifurcation and extended to expose a part of the left portal vein .Access to the left portal vein and the bifurcation facilitates clamping and inflow to the remnant left lobe can be assessed

ACCESSORY BRANCHES

Mostafa Atri (1992) described accessory branch to right posterior segment from MPV.

Van Leeuween (1994) observed accessory branch from RPV in 6 out of 10 subjects. He also observed double supply to segment 3.

K.Maheswari (2011) observed accessory branches to right posterior segment from main portal vein in 1 specimen and from right portal vein in 3 specimens. She also observed accessory branches to segment III from pars umbilicalis of LPV in 3 specimens.

The **present study** showed accessory branch to segment III from left side of PU (LPV) in 3 specimens. Accessory branch from RPV to quadrate lobe was observed in 2 specimens. Accessory branch to segment VI from RPD and right postero inferior branch was observed in 4 specimens.

RELATIONS OF PORTAL VEIN WITH HEPATIC VEIN

Melnikoff (1924), **W.Henry Hollinshead (1976) Van Leeuween (1994)** , **Susan standring (2008) K.Maheswari**, observed right hepatic vein between right anterior division and right posterior division, middle hepatic vein between the 2 branches of main portal vein and left hepatic vein between the lateral superior branch and lateral inferior branch.

The **present study** also observed that right hepatic vein was between right anterior and right posterior segments, middle hepatic vein was between

right and left branch of portal vein, left hepatic vein was between 2nd and 3rd segments of liver.

The intra-hepatic course of midhepatic vein and its relation to right hepatic vein, gives an appropriate plane of transaction.

CT PORTOGRAPHY

In all the 25 images the usual mode of formation of portal vein was observed. The normal branching pattern of portal vein, right portal vein, left portal vein, right anterior segment branch, right posterior segment branch was observed.

CONCLUSION

The study of portal vein and its branching pattern has been a great interest among anatomists, surgeons and radiologists as it has wide clinical, surgical and radiological implications. The portal vein was studied by dissection and radiological methods. The formative tributaries, level of formation, length, relations, division, branching pattern were studied. Right and Left branch of portal vein, branch to caudate and quadrate lobe, accessory branches and relations of portal vein with hepatic vein were also studied. After detailed study the following conclusions were obtained.

1. The portal vein was formed by the union of superior mesenteric and splenic vein in 92% of cases. In 4% of cases it was formed by the union of SMV, SV and IMV, here IMV opens at the confluence of SMV and SV. In 4% of cases it was formed by the union of SMV and SV, here IMV opens into SMV.

2. The portal vein was observed to begin at the L2 vertebral level in all cases taken for study.

3. The length of portal vein averages 7-8 cm in all cases taken for study.

4. In all cases the portal vein was behind to the common bile duct and hepatic artery at porta hepatis.

5. The division of portal vein was extra-hepatic that is at porta hepatis in all the specimens taken into consideration.

6. The portal vein bifurcated into right and left branch in 84% of cases. In 16% of cases PV terminated in trifurcation pattern. In trifurcation pattern of PV, type 1 is observed in 8% and type 2 in 8%

7. The RPV originated from MPV in 84% of specimens. In the remaining 16% the right portal vein was absent or replaced by its branches. The length of RPV was between 0.5-2.0cm. The RPV was bifurcated in (18) 85.68% of specimens, trifurcated in (3) 14.32% of specimens. In case of trifurcation pattern RPV divides into RAD, right postero superior and right postero inferior.

8. The RAD originated from RPV in 84% of cases and in remaining cases from MPV. In all specimens RAD divided into antero superior and antero inferior branches.

9. The RPD originated from RPV in 84% and from MPV in the remaining specimens. RPD divides into postero superior and postero inferior.

10. LPV originated from MPV in all specimens. In all specimens LPV has 2 parts. The length of LPV (extra-hepatic, i.e. horizontal part/PT) was between 2-5cm. LPV terminated by giving LSB, LIB, medial branch and

branch to caudate lobe in all cases taken for study. In 3 specimens accessory branch to segment III was observed from pars umbilicalis.

11. The left part of caudate lobe received its portal supply from PT of LPV in all specimens. The right portion received its portal supply from PT of LPV in 76%, from RPV in 4%, from portal trunk in 20%.

12. 3-5 portal branches to quadrate lobe from medial side of PU of LPV were observed in all specimens. It also received accessory branch from RPV in 2 specimens.

13. Accessory branch to segment III from left side of PU (LPV) was observed in 3 specimens. Accessory branch from RPV to quadrate lobe was observed in 2 specimens. Accessory branch to segment VI from RPD and right postero inferior branch was observed in 4 specimens.

14. RHV was present between RAD and RPD of RPV in all specimens. MHV was present between right and left branch of portal vein in all specimens. LHV was present between at right angles to lateral superior and lateral inferior branches of LPV.

In the radiological study done, normal branching pattern with respect to portal vein, 1st order branches and 2nd order branches were observed in all CT portography.

They are variations with respect to formation of PV, branching pattern of PV, branching pattern of 2^{nd} and 3^{rd} order branches of PV. This study will be useful to the surgical gastroenterologist and radiologists for interpretation and interventional procedures.

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MASTER CHART

Sl. No.	Formation of PV	Branching pattern of PV	Mode of Termination of RPV
1	1	B	B
2	1	B	B
3	1	B	B
4	1	B	B
5	1	B	B
6	1	B	B
7	1	B	B
8	1	B	B
9	1	B	B
10	1	B	B
11	1	B	B
12	1	B	B
13	1	B	B
14	1	B	B
15	1	B	B
16	1	B	B
17	1	B	B
18	1	B	B
19	1	B	T
20	1	B	T
21	1	B	T
22	1	T-P1	
23	1	T-P1	
24	2	T-P2	
25	3	T-P2	

1 - SMV + SB, 2 - SMV + IMV + SB, 3 - SV + SMV, IMV
B - Bifurcation, T-P1 - Trifucation Pattern 1, T-P2 - Tifurcation Pattern.
B - Bifurcation, T - Trifurcation,

Fig.1(a): Portal Vein Formation

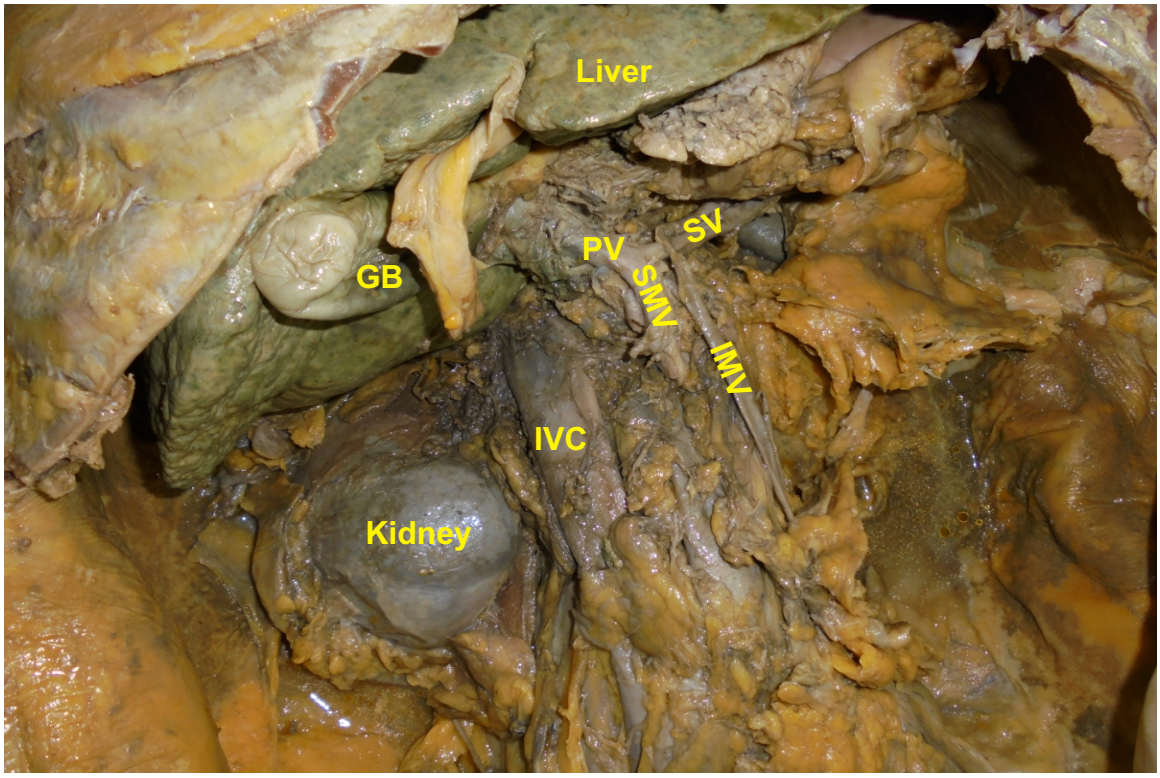

Fig.1(b): IMV opens into SMV

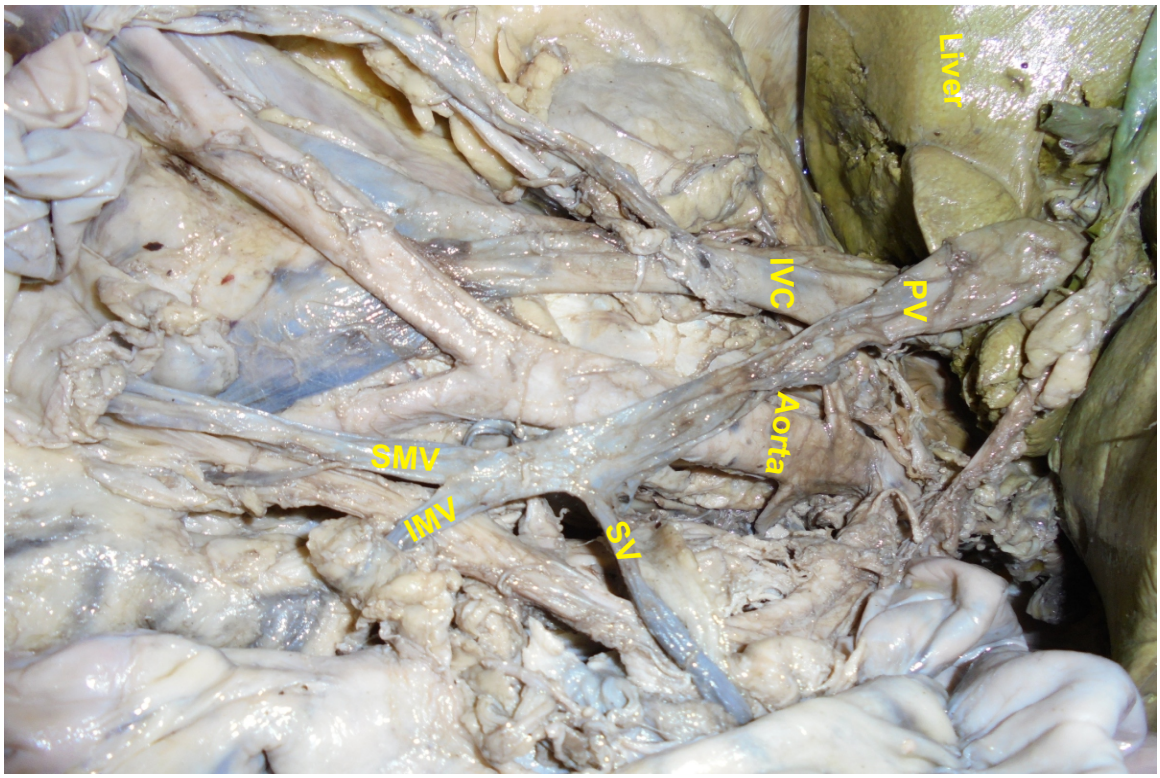

Fig.1(c): IMV opens at the confluence of SMV and SV

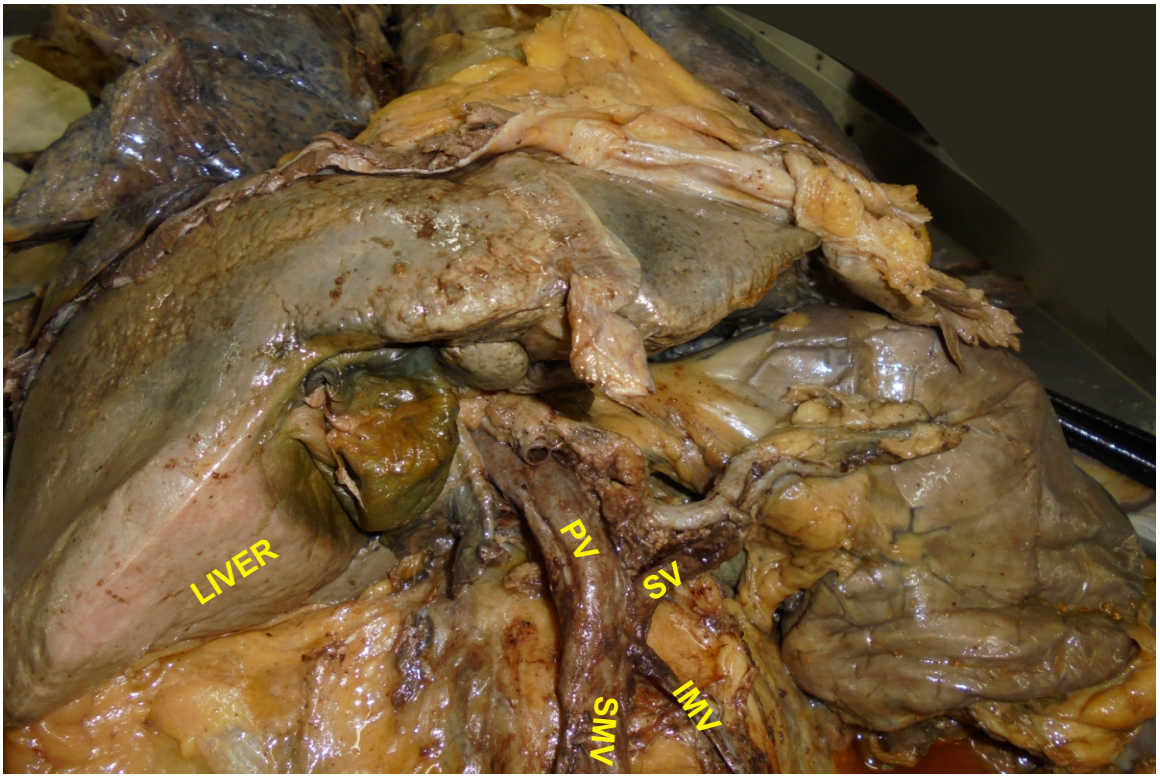

Fig.2: Relations of Portal vein

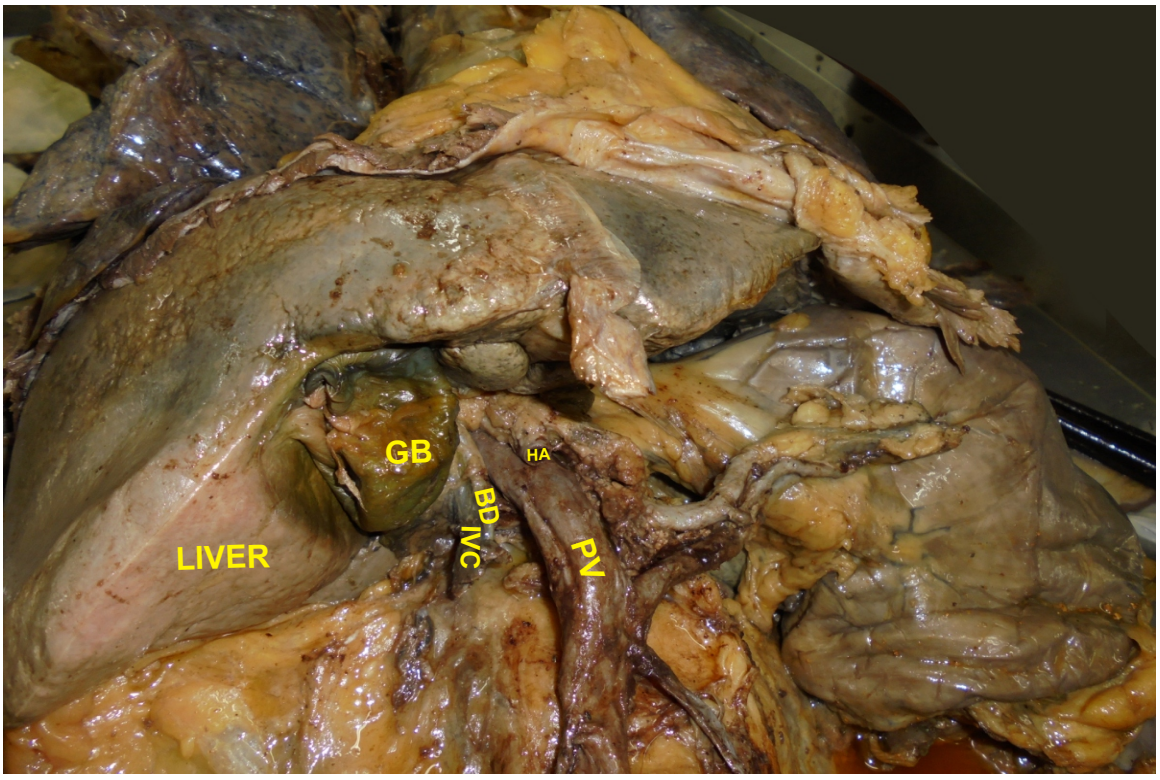

Fig.3: Division of Portal Vein at porta hepatis

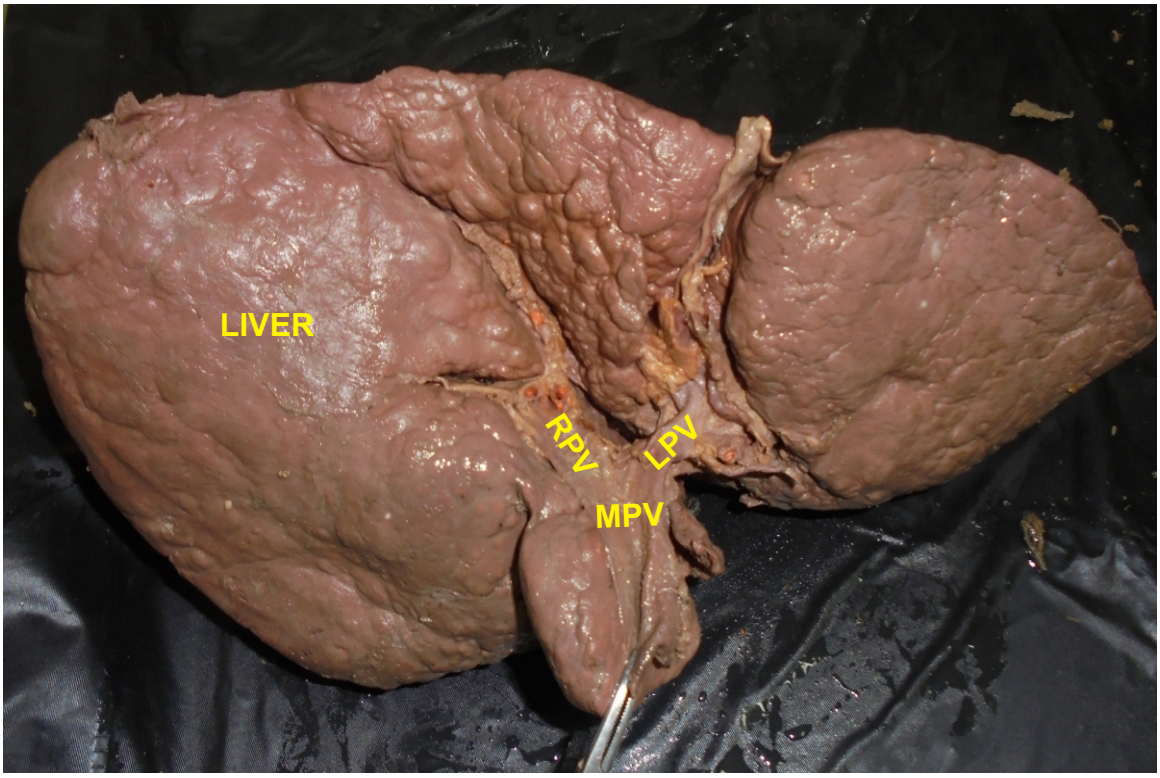

Fig.4: Normal - Bifurcation pattern of PV

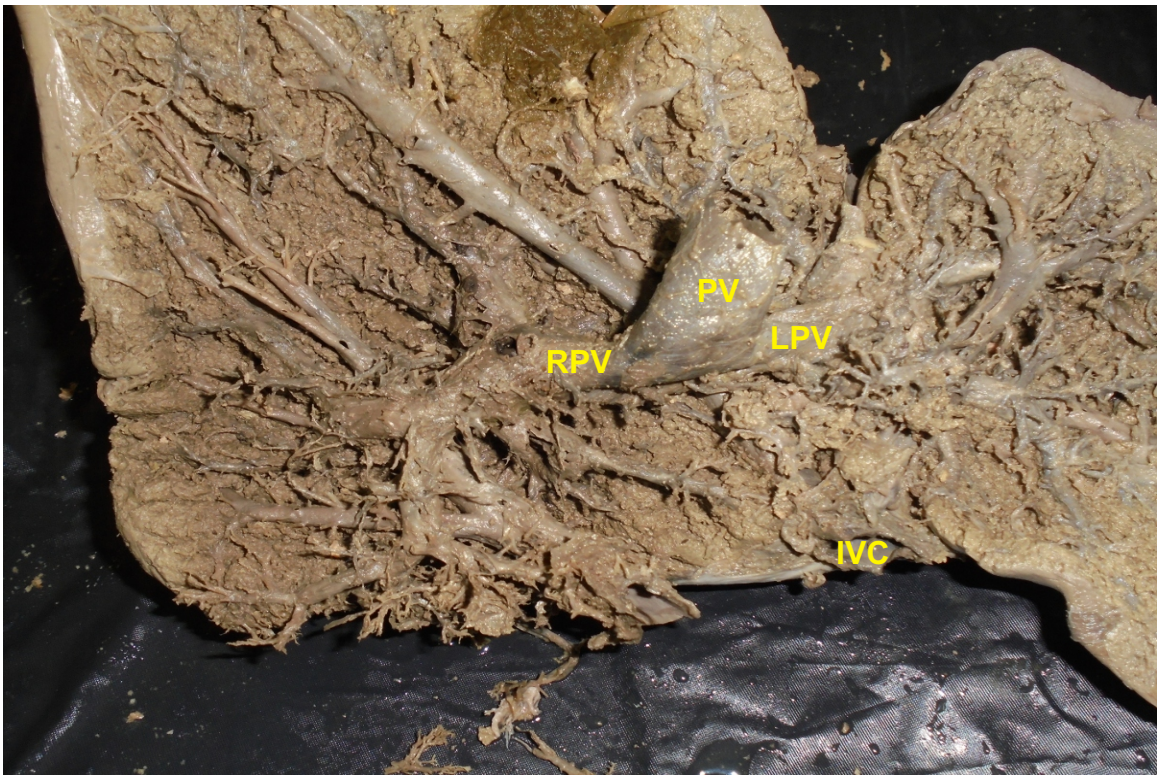

Fig.5: Trifurcation of Portal vein, Pattern - I

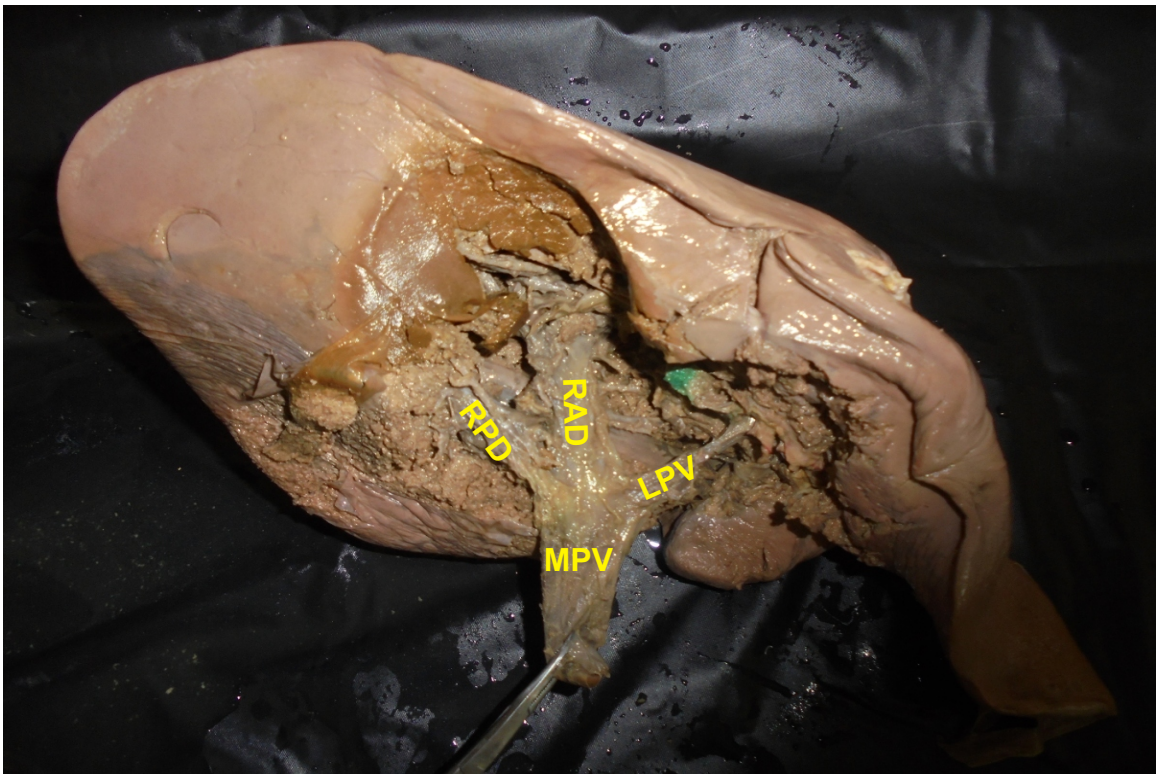

Fig.6: Trifurcation of Portal vein Pattern - II

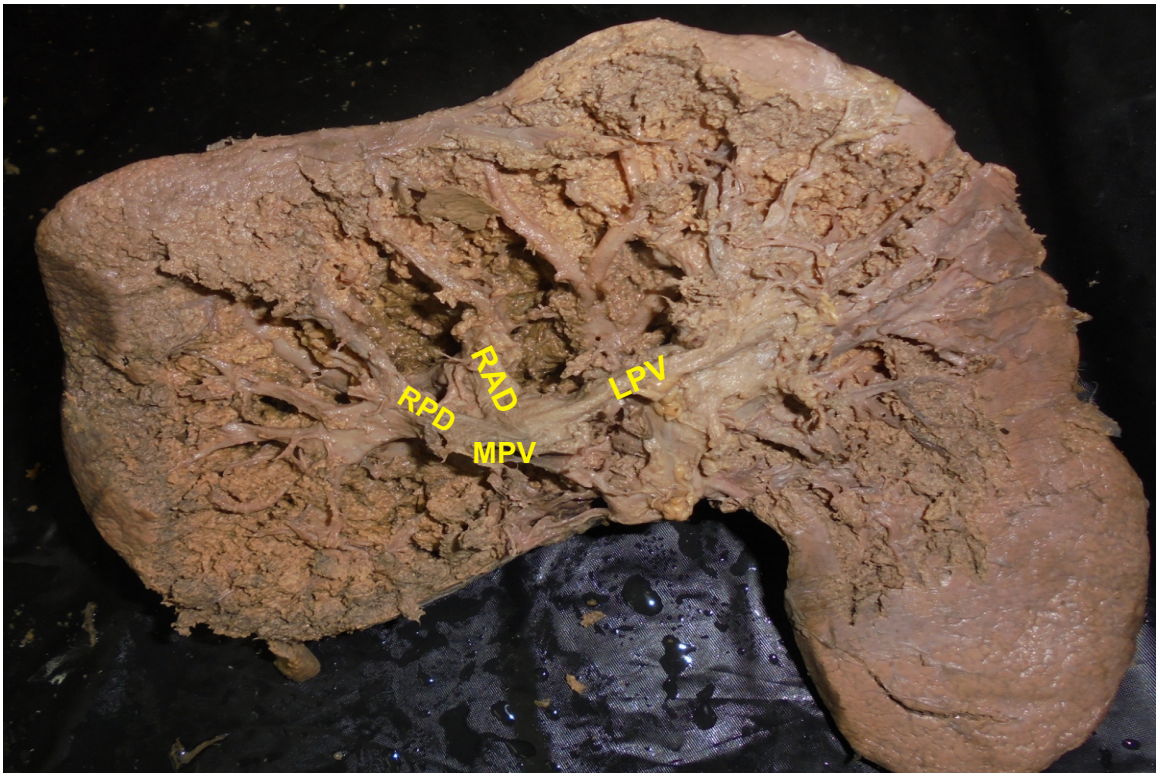

Fig.7: Standard 2nd and 3rd order branches of RPV

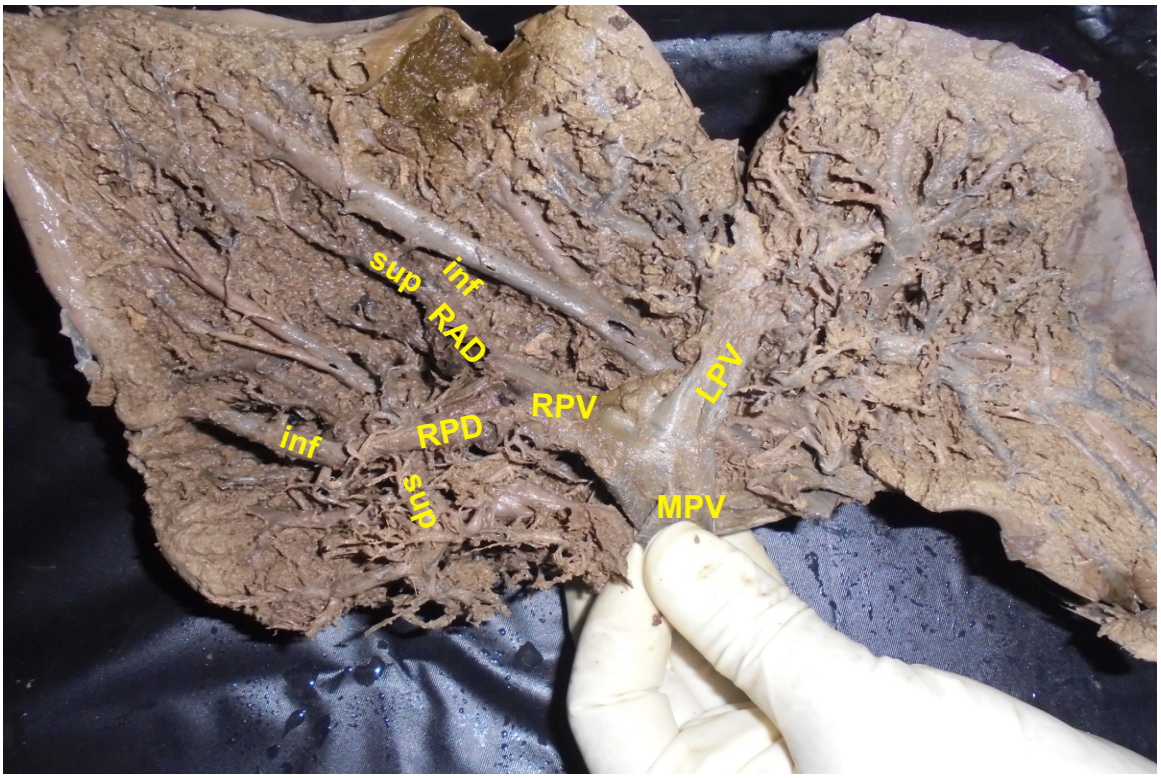

Fig.8: CT Portogram showing standard PV anatomy

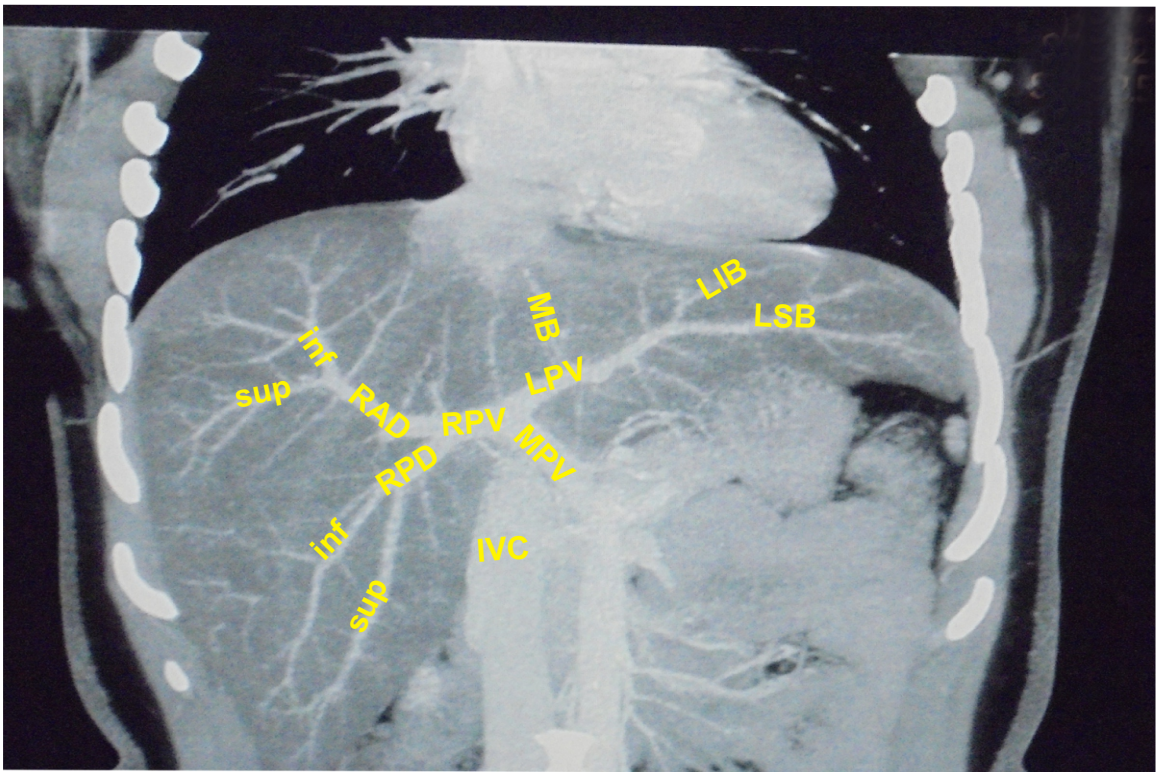

Fig.9: Second order branches of LPV

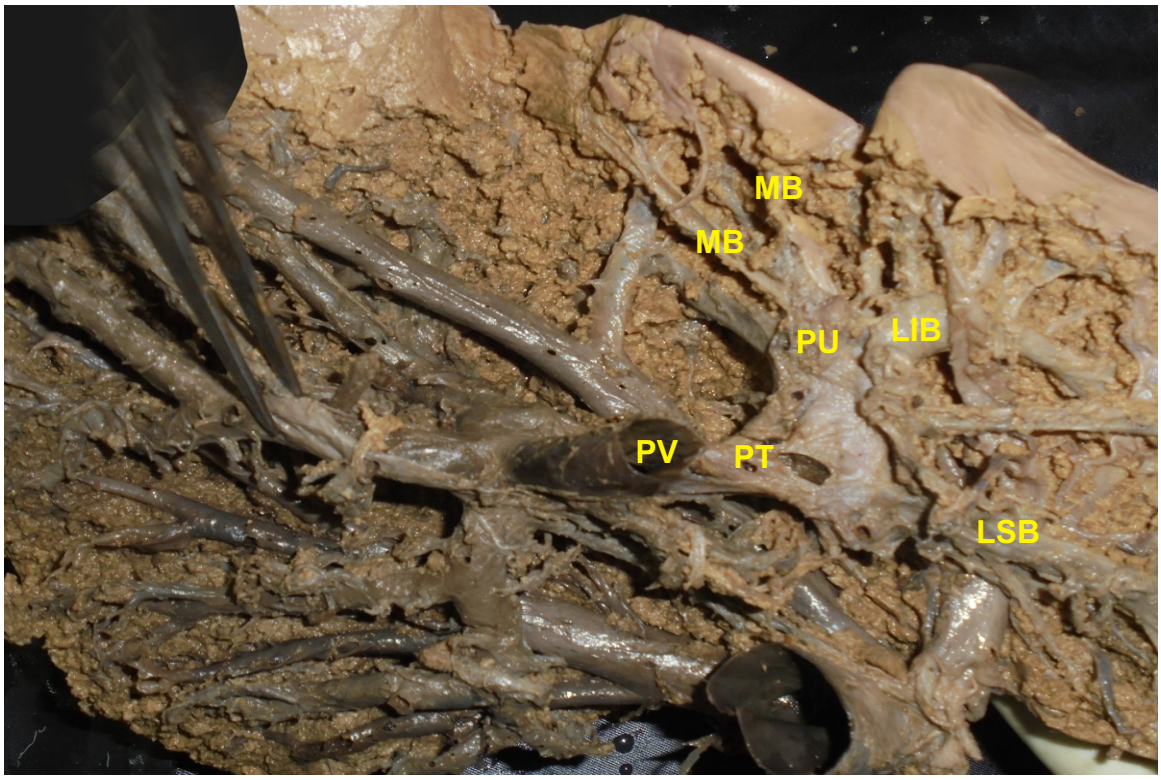

Fig.10: Branches to caudate lobe

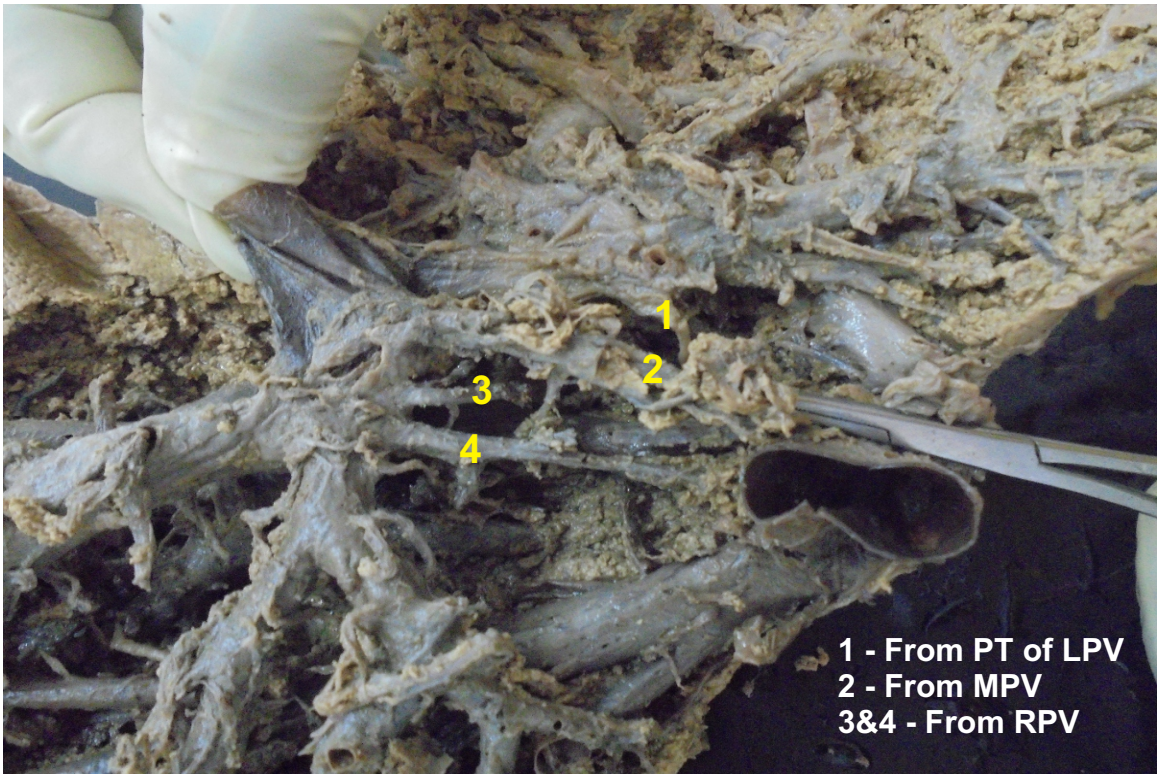

Fig.11: Branches to quadrate lobe from PU of LPV

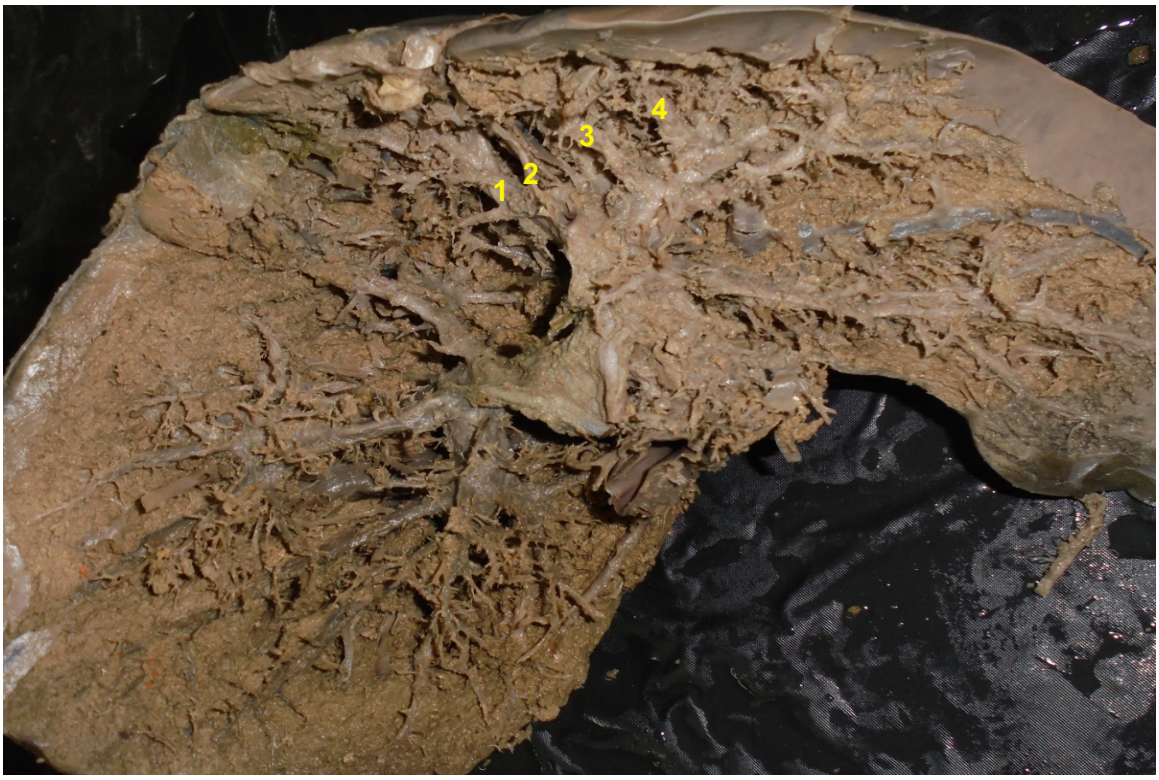

Fig.12: Accessory branch to Segment III from PU of LPV

Fig.13: Accessory branch to quadrate lobe from RPV

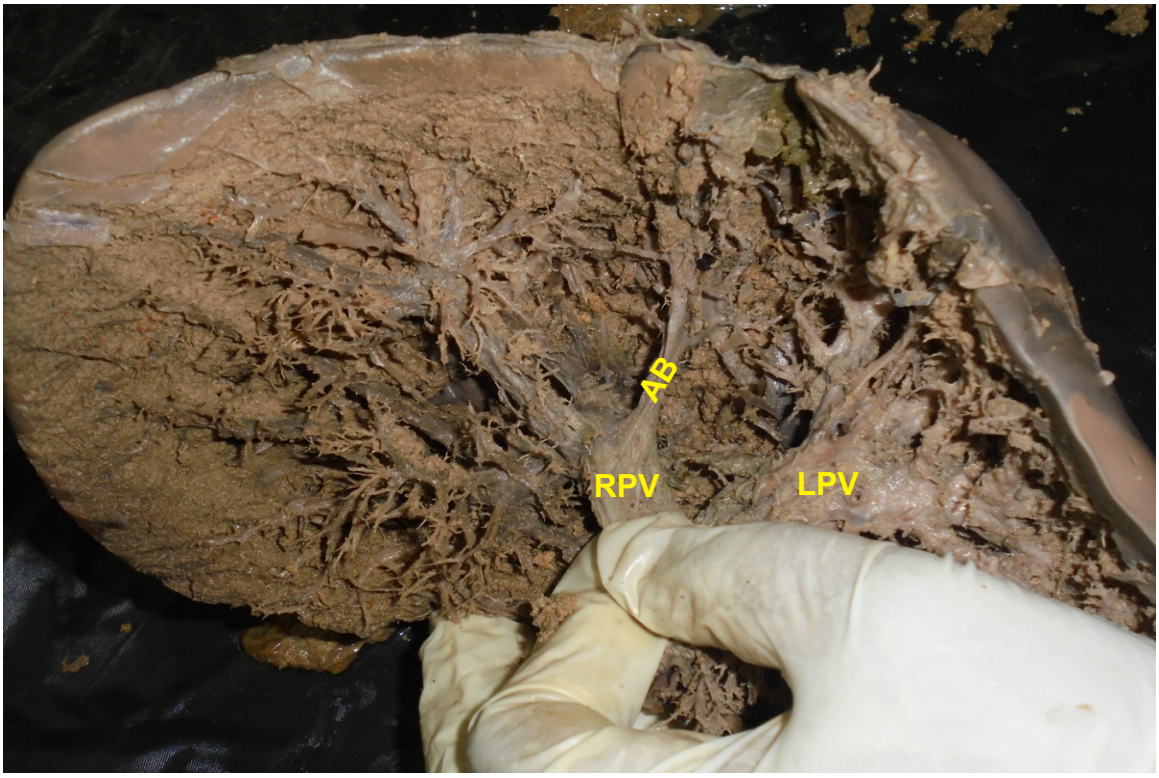

Fig.14: Accessory branch to Segment VI from RPD

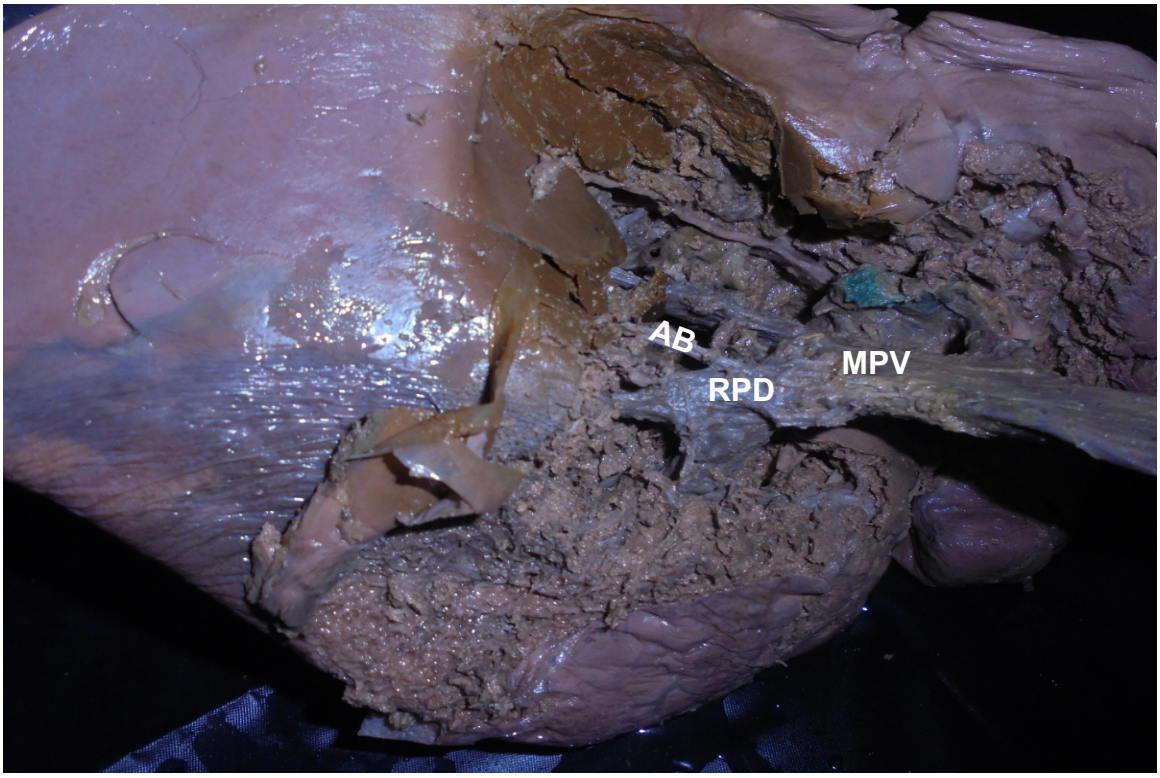

Fig.15: Relations of portal vein and hepatic vein

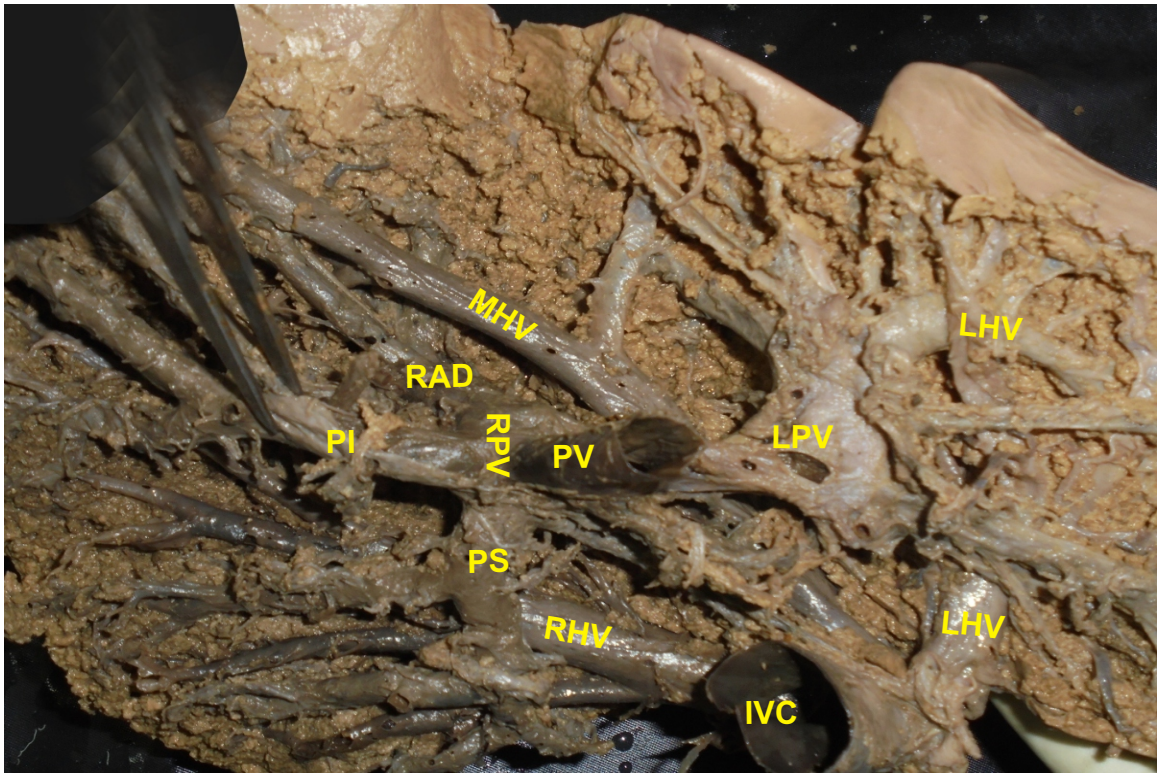

Fig.16: CT portogram showing relations between portal vein and hepatic vein

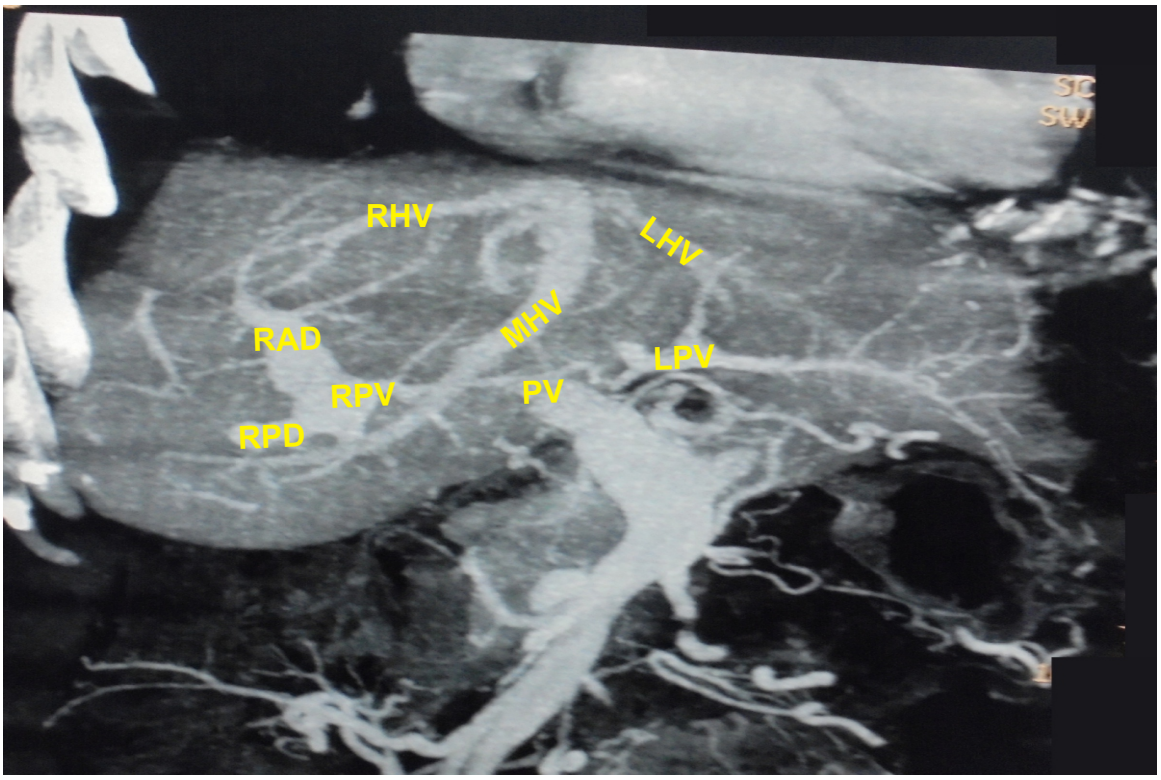

Fig.17: Trifurcation of RPV